REPETITION AND DISTRIBUTION EFFECTS ON MEMORY: A PSYCHOPHYSIOLOGICAL ANALYSIS

By

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REPETITION AND DISTRIBUTION EFFECTS ON MEMORY: A PSYCHOPHYSIOLOGICAL ANALYSIS

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A phenomenon of central importance for the study of human memory processes is the consistent finding that the long-term memory (LTM) for repeated stimuli depends upon the amount of time or the number of different stimuli intervening between the first presentation (P1) and second presentation (P2) of the stimulus. The LTM for repetitions is generally not much better than that for once-presented items when P1 and P2 are successive and temporally close, but increases as P1 and P2 become more distributed in time and separated by the presentation of other items. Evidence suggests that the use of psychophysiological responses to assess momentary processing demands of individual stimuli may help clarify the locus of repetition and distribution effects. This paper reports the results of research employing both a free-recall test of LTM and cardiac and electrodermal responses to explore the relationships between repetition and memory.

Three experiments were performed, each of which involved presenting college students with controlled lists of words. Some words were presented twice within each list while others occurred only once. Dependent measures of primary interest were the proportion of words correctly recalled and the magnitude of heart rate (HR) deceleration and phasic skin conductance responses (SCRs) evoked by each word presentation. In the first experiment, recall for repeated words was significantly influenced by the number of intervening items (lag) separating P1 and P2. Only HR was recorded in Experiment 1, and it was found that P2-evoked deceleration was significantly greater than the P1 response. The P2 response was not differentially affected by lag. It was suggested that uniformly larger decelerative P2 responses and an overall greater recall for repetitions were the result of the low frequency of occurrence of repetitions, i.e, an isolation or uncertainty effect which caused greater attention to be devoted to all repetitions.

The design of Experiment 2 reduced the uncertainty associated with the occurrence of a repetition. Recall for repeated words was significantly greater with a distributed than with a massed presentation schedule. The HR deceleration and SCRs evoked by P2 presentations were reliably greater under the distributed schedule. A reliable decrement in the P2-evoked SCR relative to the P1 response was also found with the massed schedule, and the HR responses showed a similar pattern.

Experiment 3 revealed that temporal spacing alone is at least partly a determinant of repetition effects. Recall for repeated words was reliably greater when 20 sec separated P1 and P2 than when 10 sec intervened, but the magnitude of the difference was considerably smaller than the distribution effect in the second experiment. The general

pattern of results for the two psychophysiological measures was similar to that found in Experiment 2, but the response differences were less pronounced and were significant only for the electrodermal measure.

The results from the three experiments were interpreted as evidence that the locus of repetition and distribution effects are identifiable with the differential processing of P2, and that deficient processing of successive, temporally close repetitions is responsible for the relatively poor LTM for such stimuli. An attentional explanation for these effects was proposed and related to the framework adapted by two-process models of human memory and a recent theory of habituation and animal memory developed by Wagner. The usefulness of a synthesis of theory and methods from the fields of psychophysiology and information processing was confirmed, and the implications of a psychophysiology of memory for the study of memory development were discussed.

INTRODUCTION

Repetition is a fundamental process of learning and memory. Habituation, the establishment of a conditioned response, and the extraction of relevant attributes in a concept learning task are all realized through the process of repetition. The enormous range of complexity, of both organisms and stimuli, in which this process manifests itself is truly remarkable. Yet the parameters which determine the effectiveness of repetition are still not clearly understood, especially when the stimulus or task requires high-level processing and the involvement of a complex memory system.

In the most simple case, iterative presentation of a nonsignal stimulus results in the habituation of some measured aspect of an organism's behavior, usually a physiological or basic behavioral response. This effect of repetition is quite pervasive and readily occurs in animals and humans. While such decrements in activity can be found at all levels of the nervous system, there is considerable support for the involvement of memory apart from any contributions of adaptation or receptor fatigue (Sokolov, 1963; Wagner, 1976; Whitlow, 1975). Silverstein and Berg (1977) have reviewed the evidence that psychophysiological responses, in addition to reflecting memory for a given stimulus, are also useful as indicators of attentional processes and cognitive effort.

Complex human memory experiments typically rely on complex response measures to infer underlying processing, the result often being an inability to accurately delineate the components which determine the response. The measurement of both verbal responses and psychophysiological activity from one or more response systems can be advantageous in this respect, particularly if the effects of stimulus repetition are of primary interest. This dissertation is an attempt to apply such a synthesis to a prominent problem in the field of psychology.

A phenomenon of central importance for the study of human memory processes is the consistent finding that the beneficial effects of repetition on memory are a function of the amount of time or the number of different stimuli intervening between the first presentation (P1) and the second presentation (P2) of a repeated stimulus (Crowder, 1976; Hintzman, 1974, 1976). Long-term memory (LTM) for repeated stimuli generally shows little improvement over singly presented stimuli when P1 and P2 are successive and temporally close. However, an increase in LTM for repeated stimuli occurs as P1 and P2 become more distributed in time and separated by the presentation of other items. These effects of the scheduling of repetitions are reversed when a test of short-term memory (STM) is used. That is, STM for repeated stimuli is best when P1 and P2 are successive and close together in time.

The effects of the spacing of repetitions on memory are extremely general. They are not specific to any particular memory paradigm, retention test, type of material to be remembered, modality of stimulus presentation, or rate of stimulus presentation. However, the free-recall paradigm has been used extensively, and two classic experiments using this procedure will serve as a point of reference to illustrate the general effects.

Melton (1967) and Madigan (1969), in two essentially identical experiments, presented subjects with lists of words to be remembered. Words were displayed visually at a rate of 1.5 sec per word. Some words occurred only once in a list, while others occurred twice. For repeated words, P1 and P2 were separated by either 0, 2, 4, 8, 20, or 40 presentations of other words (i.e., the lag at which a word was repeated). The eight items at the very beginning and very end of each list served to absorb primacy and recency effects and were excluded from the analysis of subjects' free-recall performance. The major important findings were that recall probability for words repeated at Lag 0 was not much higher than for singly presented words, and recall probability for repeated words was a systematically increasing function of lag. The greatest improvement in recall for repeated words occurred between Lag 0 and Lag 2. These basic findings have been replicated many times. In addition, Melton (1970) has shown that the lag effect in free-recall occurs independently of the rate (between 1.3 and 4.3 sec per word) and modality (visual or auditory) of stimulus presentation.

Crowder (1976) has suggested that the results of the Melton (1967) and Madigan (1969) studies are a function of several different phenomena. The fact that recall generally improves under all conditions in which an item is repeated is called a repetition effect. The large and consistent increase in performance found when the presentation of at least some other items separate P1 and P2, than when P1 and P2 are successive, is referred to as a distribution effect. Additionally, increments in performance which occur as a function of the number of different stimulus presentations intervening between P1 and P2 is most appropriately termed the lag effect. This differentiation of effects has utility since long-lag and distribution effects can be

independently influenced by certain manipulations. For example, D'Agostino and DeRemer (1973) found that forcing the same encoding for P1 and P2 of a repeated word eliminates long-lag effects but not the distribution effect. Gartman and Johnson (1972) showed that the lag effect in recall probability for repeated homographs, words with more than one meaning, can be disrupted by systematically biasing their encoding toward different meanings at the two occurrences. In addition, experiments employing the continuous paired-associate memory paradigm have found an inverted-U shaped lag function when short or intermediate retention intervals are used (Glenberg, 1976; Peterson, Wampler, Kirkpatrick, & Saltzman, 1963); however, the lag function approaches the monotonic increases in performance found with the free-recall paradigm as the retention interval becomes longer (Glenberg, 1976). While the lag function is rather easily influenced, the distribution effect appears almost invariant across a wide range of manipulations.

Underwood (1969) investigated the effects of massed and distributed presentation of repeated words on a free-recall performance. Massed presentation (MP) means that P1 and P2 for repeated words are successive. Distributed presentation (DP) indicates that the presentation of at least some other words separate P1 and P2. In the first two experiments, lists of words were mixed such that MP, DP, and singly presented words occurred within the same list. Words were auditorily presented at a rate of 5 sec per word. The results revealed an obvious overall superiority of DP over MP. In addition, MP words were hardly remembered better than words presented only once. A third experiment using unmixed lists closely replicated the findings from the first two studies. Underwood (1970) obtained similar results when either sentences or nonsense syllables were used instead of words.

Distribution effects also occur with the continuous paried-associate procedure. Peterson, Hillner, and Saltzman (1962) and Peterson et al. (1963) have found that recall probability for the response term of a repeatedly presented paired-associate varies as a function of both the distribution between P1 and P2 and the length of the retention interval. If the recall test comes very soon after P2 of a paired-associate (e.g., 2 sec), MP shows superior performance to DP. With longer intervals between P2 and the recall test the situation reverses, and DP response terms are recalled more frequently than MP terms. The direction of the distribution effect appears to depend on whether a test of STM or LTM is used, at least for the continuous paired-associate procedure. The findings with respect to the longer retention intervals are very much in accord with the studies cited earlier. The superiority of MP found for STM is of great interest but has not been the subject of much investigation using other paradigms. However, a similar advantage of successive over distributed repetition has been found with the immediate memory span technique (Crowder, 1968).

Hintzman (1974, 1976) has suggested that the most consistent finding across paradigms, retention tests, and materials to be remembered is the increases in LTM which occurs as a function of increases in the time between P1 and P2 up to approximately 15 or 20 sec. He named this phenomenon the "spacing effect" and presents some evidence that it asymptotes at about 15 sec. The continued increases in performance found at lags extending beyond 15 sec or so, and the paradoxical superiority of MP over DP with tests of short-term retention are not considered under the rubric of the spacing effect. Hintzman proposed that the processes responsible for these phenomena are not the same as

those which cause the spacing effect. Distribution effects with paradigms using a long-term retention test and the increases in performance found across short lags are considered to be synonomous with the spacing effect. He does indicate, however, that the temporal parameters of the spacing effect may vary somewhat depending on the materials and other experimental manipulations. It is worth mentioning that while spacing is defined in terms of the amount of time between P1 and P2, such time is typically determined by the number of intervening stimuli and the presentation rate. Evidence from another body of literature, some of which will be discussed later in this paper, suggests that time and number of intervening stimuli may make independent contributions to the effects of the spacing of repetitions. For the most part, however, this writer is in agreement with the definition and constraints proposed by Hintzman.

In noting the generality and ubiquity of the spacing effect, Hintzman (1974) contends that some very basic processes may be involved. Moreover, he points out that the effect cannot be predicted from two otherwise useful principles in human memory. The law of recency is contradicted by the fact that retention decreases as P1 occurs closer in time to P2, i.e., as P1 becomes more recent. The total-time law states that, within certain limits, retention of an item is a direct function of the total study time devoted to it regardless of how that study time is distributed (Cooper & Pantle, 1967). Since the total amount of time for which an item is presented is independent of the spacing or distribution between P1 and P2, this principle is contradicted as well.

The question as to what processes are responsible for the spacing effect has yet to be answered satisfactorily. A number of alternative

theoretical explanations for the effects of the spacing of repetitions have been proposed. None are conclusive; they differ primarily in whether they attribute the effects to deficiencies in the processing of P1 or P2 and in assuming either voluntary or involuntary origins for such deficiencies. The major concepts which have been invoked as an explanation are memory consolidation (Landauer, 1967, 1969; Peterson, 1966), rehearsal (Atkinson & Shiffrin, 1968; Rundus, 1971), voluntary allocations of attention (Glanzer, 1969; Greeno, 1970; Underwood, 1970), habituation (Hintzman, 1974, 1976), and encoding variability (Glenberg, 1976; Madigan, 1969; Melton, 1970).

The memory consolidation and rehearsal notions both assume that the locus of the spacing effect is at P1. The proposal is basically that ongoing processing of P1 is halted or disrupted by P2, which recruits processing capacity for itself. Deficiencies in the processing of P1 are therefore inversely related to the spacing between the two presentations. The difference between the two approaches is primarily a matter of whether processing is assumed to be involuntary, i.e., an autonomous consolidation process, or voluntary in the sense of subject-controlled rehearsal. Neither seems tenable since evidence from a modality-tagging experiment has indicated that it is the retention of P2 and not P1 which varies as a function of spacing (Hintzman, Block & Summers, 1973). In addition, Bjork and Allen (1970) found that recall of repeated words was better when a difficult interpolated task separated P1 and P2 than when an easy task separated the two presentations. A difficult task should undoubtedly have caused more interference with either the consolidation or rehearsal of P1, but the fact that recall was better in this situation casts serious doubt on any account of the spacing effect which predicts differential processing of P1.

Explanations based on allocations of attentional capacity presume that either boredom or the presence of P1 in STM cause the subject to devote less than a full measure of attention to P2. There are several advantages to this approach. First, it is assumed that variations in the processing of P2 are a function of its proximity to P1. That is, more attention is devoted to P2 if there is some delay or other items intervening between it and P1. The results of the Hintzman et al. (1967) and Bjork and Allen (1970) studies are in good agreement with this proposition. A second advantage is that such an account of the spacing effect is very much in accord with the literature on the orienting response (e.g., Sokolov, 1963), and may also be relevant to similar repetition phenomena observed with infra-human subjects (Wagner, 1976; Whitlow, 1975). If the allocation of attention is somehow involuntarily controlled, as Hintzman (1974) suggests, then the spacing effect and the parameters which influence it would appear to parallel the process of habituation and its determinants.

What evidence there is for the involvement of attentional processes is of an indirect sort. For example, Shaughnessy, Zimmerman, and Underwood (1972) found that subjects given the opportunity to control the exposure time of visually presented words spent more time studying P2 items on a DP schedule than on an MP schedule. Subjects' recall performance showed a corresponding distribution effect. Elmes, Greener, and Wilkinson (1972) reasoned that if less attentional capacity is allocated to P2 when repetitions are massed, then some leftover capacity might be applied to items after P2. This is, in fact, what they found. Recall for words presented immediately after P2 was better when P1 and P2 were successive than when they were distributed. This

compensatory increase in performance on nearby noncritical items suggests that the allocation of a fixed processing capacity is involved in the spacing effect.

Studies which have attempted to eliminate or attenuate the spacing effect via manipulations designed to insure an even distribution of attention to all stimuli have generally not been successful (D'Agostino & DeRemer, 1973; Elmes, Sanders, & Dovel, 1973; Hintzman, Summers, Eki, & Moore, 1975). In addition, Shaughnessy (1975) found that the effect occurs even in incidental learning situations. While such findings have been taken as evidence that the allocation of attentional capacity to P2 is not volitional (Hintzman, 1975, 1976), one might just as well argue that attention to the stimulus is not the critical factor responsible for the spacing effect.

Explanations based on encoding variability theory do not assume a deficiency in the processing of either P1 or P2, but instead emphasize shifts in context between the two presentations. At short spacings P1 and P2 sample virtually the same contextual elements and there is considerable overlap in their encoding. As the spacing between the two presentations increases, there is a corresponding increase in the probability that P1 and P2 will be associated with different contextual cues and become uniquely encoded. The theory basically predicts that the more different encodings or contextual associates a stimulus has, the greater is the likelihood of its retrieval at a later time. There is little experimental support for encoding variability as an explanation of the spacing effect (Hintzman, 1976). The evidence that contextual shifts are responsible for long-lag effects is considerably better (Glenberg, 1976). It seems intuitively reasonable that substantial

shifts in context between P1 and P2 would occur at long lags, and this is wholly consistent with the frequently obtained monotonic increases in recall performance. Moreover, changes in the context in which a stimulus is presented can modulate attentional capacity (Kahneman, 1973; Pribram & McGuinness, 1975; Sokolov, 1963) and, as Crowder (1976) has suggested, the lability of attentional capacity and encoding variability appear to be complementary explanations of spacing and lag effects.

Despite the lack of strong empirical support, the most promising explanation of the spacing effect seems to involve variations in the allocation of central processing capacity. An unobtrusive measure of momentary processing demands at the time of occurrence of P1 and P2 would be an invaluable asset for evaluating this proposal. Not only could the locus of the effect be identified, but the parameters which determine the effectiveness of repetition and the resulting influence on memory could be systematically investigated as well. Psychophysiological responses are unique in satisfying the requirements for an unobtrusive measure of attention and processing effort.

Phasic arousal responses have been variously implicated as reflecting the elicitation of the orienting response (Graham & Clifton, 1966; Sokolov, 1963, 1969), changes in attention and perceptual sensitivity (Kahneman, 1973; Lacey, 1967; Pribram & McGuinness, 1975), and variations in the allocation of processing capacity and mental effort (Kahneman, 1973; Pribram & McGuinness, 1975). In addition, it is now well established that arousal and habituation are at least partly controlled by high level functions and involve the participation of the memory system (see Silverstein & Berg, 1977 for a complete review of these topics).

Of particular interest for this paper is the bidirectional nature of the heart rate (HR) response. It has been consistently found that HR deceleration accompanies situations requiring orienting or attention to the external environment; on the other hand, HR acceleration and other sympathetic manifestations of arousal generally occur during very effortful mental processes (e.g., mental arithmetic or maintenance rehearsal) or in response to high intensity stimulation (Graham & Clifton, 1966; Lacey, 1967; Lacey, Kagan, Lacey, & Moss, 1963; Tursky, Schwartz, & Crider, 1970). Thus, the HR response permits the differentiation of external and internal processing demands, an obvious benefit where memory tasks involving both attentional and rehearsal processes are concerned. Measures such as skin conductance usually show a sympathetic-like increase in activity during both the attentional and cognitive effort phases of most psychological tasks, although there is some evidence that skin conductance is not particularly sensitive to maintenance rehearsal (Tursky et al., 1970).

The measurement of cardiac and electrodermal responses evoked at the time of individual stimuls presentations along with the subsequent long-term recall of these events provides a powerful technique for investigating repetition and distribution effects on memory. The following three experiments are based on this strategy.

EXPERIMENT 1

The initial experiment was designed to meet three major objectives. The first was to replicate the free-recall lag function previously found by Melton (1967) and Madigan (1969) and also the Elmes et al. (1972) finding that noncritical items following repetitions at a zero or short lag are recalled better than those following repetitions at a long lag. A second objective was to determine the form of the HR response evoked by meaningful verbal stimuli associated with a memory task. A biphasic response was anticipated: a small initial HR deceleration reflecting attentional processes followed by HR acceleration during the period of stimulus rehearsal (Tursky et al., 1970). The third major objective was to explore the possibility of differential processing of P1, P2, and noncritical stimuli following repetitions.

It was predicted that differential processing would influence the HR response and appear primarily as variations in the magnitude of the deceleratory component with little effect on the subsequent rehearsal-related acceleratory component. If repeating a stimulus at a lag of zero (i.e., an MP schedule) results in little or no improvement in the long-term memory for that stimulus because of a lack of attention to P2, then the HR response evoked by P2 should show a smaller deceleratory component than the P1-evoked HR response. As the lag between P1 and P2 increases, the P2-evoked HR deceleration should increase in correspondence with improvements in long-term recall. The deceleratory response to

stimuli after repetitions should decrease across lags if the argument that compensatory allocations of attentional capacity are applied to such stimuli is correct. Thus, it was predicted that both the long-term recall of repeated stimuli and P2-evoked HR deceleration would increase as a function of the lag between repetitions, while the recall and HR deceleration for noncritical stimuli following repetitions would be inversely related to lag. The P1-evoked HR deceleration was not expected to vary across lags. In addition, the acceleratory component of the HR response was expected to be relatively invariant across lags and presentation types. There is no reason for the amount or rate of information rehearsed after P1 presentations to be affected by the presentation of P2. The rehearsal of P2 and stimuli following repetitions could indeed vary as a function of lag; however, these differences would probably not be reflected in HR because subjects could maintain an optimal rehearsal load by simply choosing to rehearse other previously presented stimuli. If differences in rehearsal-related HR acceleration were to occur they would only be of secondary interest since, as Hintzman (1974) has pointed out, differential rehearsal following repetitions is most appropriately considered a manifestation rather than a cause of the spacing effect.

Method

Subjects

Six male and six female introductory psychology students at the University of Florida served as subjects and received class credit for their participation. Subjects ranged in age from 18 to 23 years with

a mean of 20.0 years and satisfied the following selection criteria: no known history of cardiac or vascular disorders; no active hay fever, asthma, colds, or other respiratory difficultires; no use of drugs or prescription medications, other than contraceptive, within the previous 24 hours. Experimenter error necessitated the replacement of one subject, and one other subject who exhibited excessive variability in cardiac rhythm was also replaced.

Stimulus Lists and Design

Eighty-six stimulus words were selected from a pool of 320 five-letter nouns used in an earlier study (Fischler, 1973). All words were of one- or two-syllables and fell within the frequency range of 10-100 per million in Kucera and Francis (1967). The 86 words were randomly assigned to one of two 43-word lists (A or B) having a mean frequency of 34.5 and 34.9, respectively. The experimental word lists are displayed in Appendix A.

Each word list was used to construct a list of 52 presentation events consisting of 34 words presented once (1P) and 3 words presented twice (2P) at each of 3 lags: 0, 4, and 8 intervening events. In each presentation list there was an 8-event primacy buffer and an 8-event recency buffer occupying corresponding list positions 1-8 and 45-52. The buffers contained only 1P words, and their purpose was to allow the analysis of repetition and lag effects uncomplicated by the serial position effect of free recall (Murdock, 1962). Between these buffers were 36 positions containing 18 1P words and the 3 2P words for each lag value. Since the buffers were excluded from all data tabulations and analyses, these central 36 positions were designated the functional presentation list.

One exemplar of each lag condition was assigned to each third of the functional presentation list, with the constraint that at least one 1P word separated a repetition from either P1 or P2 of any other repeated word. The 18 functional 1P words were subdivided into 9 1P words and 9 words immediately following repetitions (1P'). Thus, within the functional presentation list were 9 1P words occupying 9 positions, 9 2P words occupying 18 positions (3 P1 and 3 P2 presentations at each of the 3 lags), and 9 1P' words occupying 9 positions. The average serial position of 1P words within the 52 event presentation list was 27.0. For lags of 0, 4, and 8, the average serial positions of P2 were 25.7, 27.7, and 29.7, respectively. Average positions for 1P' words were 26.7, 28.7, and 30.7 for the 3 lags. The conditional probability of any given word being repeated was .21 (i.e., .07 for each lag).

Random assignment of words from Lists A and B to events within the given presentation list structure resulted in two structurally identical presentation lists of different words (A1 and B1). In addition, two other lists (A2 and B2) were created from these by a partial rotation of 1P, 2P, and 1P' words in the functional portion of each list. The intent of this maneuver was to provide an additional means of assessing any bias in the results due to individual item selection.

Subjects were each presented and subsequently recalled one A list and one B list. List type (A - B) was a within-subjects factor, and the order in which A and B lists were presented was counterbalanced across the 12 subjects. List number (1 - 2) was a between-subjects factor: half of the subjects received Lists A1 and B1 and the other half received Lists A2 and B2. Lag and presentation type varied within both lists and subjects.

Apparatus

All stimulus generating and timing functions were controlled by a PDP-8 laboratory computer system. Stimulus lists were stored on magnetic disk and were presented by the computer on a Tektronix Type 602 display oscilloscope.

The electrocardiogram (EKG) was detected by a standard Lead II placement of Beckman Biopotential electrodes on sites scrubbed with alcohol. Electrodes were fastened with Beckman adhesive collars and micropore tape. A Beckman Type R411 Dynograph provided signal conditioning, amplification, and analog records of the EKG. The EKG was filtered with a .004-sec time constant and fed into a Beckman 9857 Cardiotachometer Coupler whose output was also displayed on the paper record. In addition, a synchronization pulse, coincident with stimulus presentation, was generated by the PDP-8 and routed to the polygraph to provide a stimulus marker. The filtered EKG, cardiotachometer output, and synchronization pulse were all simultaneously recorded on a Hewlett-Packard 3960 instrumentation recorder for subsequent computer scoring of cardiac rate. During playback, the signals recorded on magnetic tape were fed through an Iconix dual Schmitt-trigger/one-shot/level-converter combination to provide shaped TTL-level pulses appropriate for input into the computer.

The subject testing room, located adjacent to the laboratory, was furnished with a comfortable, fully-adjustable dental chair. A small instrument rack containing the Tektronix display scope was positioned approximately 1.5 m directly in front of the chair. The inside of the rack was blanked-out with a large cardboard panel such that only the scope face was visible to the subject. A Fanon intercom system enabled two-way communication between the testing room and the laboratory.

Procedure

Upon arrival at the laboratory, subjects were informed about the general nature of the experiment: that they would be presented with lists of words to be remembered, and that physiological responses would be recorded, requiring that electrodes be attached to their arms and leg. If they decided to participate, they were questioned concerning the selection criteria outlined earlier. Subjects who met these criteria were then taken to the experimental testing room for electrode placement and instructions.

When the electrodes were in place, subjects were seated in the dental chair. An example word was presented on the display scope, and the chair was adjusted so that subjects were comfortable and had a convenient view of the display. Subjects were then given a clipboard, a blank sheet of paper, and a pen to rest on their laps. The following instructions were given to all subjects:

> Two different lists of approximately 50 words each are going to be presented on the scope display. All the words will be five-letter nouns similar to the example word, and some of the words within each list will occur more than once. There are no obvious or planned associations between words or any predictable orderings of repetions. Each word will appear on the display for about 1 sec, and there will be approximately 10 sec between word presentations. Since the lists are quite long and no warning is given as to when a word will be presented, try to remain alert and keep your eyes on the display at all times. At the very end of each list, five question marks will appear on the display instead of a word. This is a signal for you to recall as many of the words from that list as you can remember, in any order you wish. The clipboard and pen are provided for that purpose. I will give you 3 min to write down the words, and then I will return from the laboratory, take your recall sheet, and replace it with another blank one. After a 5 min rest, we will proceed to the second list. It is very important that you restrict your movements as much as possible during the presentation of the lists because of the sensitivity of the recording equipment. Of course, when the

question marks appear just pick-up the clipboard and begin writing. Do you have any questions? If not, I will go to the laboratory and we will begin the experiment. When the example word disappears from the display, you will have 30 sec until the presentation of the first word of the list.

Stimulus words were composed of a series of dots. Each letter was composed of an average of 15 dots and occupied a space of approximately 1.0 cm x .75 cm. The words were centered on the scope display. Stimulus duration was 1 sec; however, due to the slow decay rate of the scope phosphors a "shadow" of the stimulus was visible for approximately 1 additional sec. A long interpresentation interval, 10 sec from onset to onset, was necessitated by the need to allow the HR response to recover between stimulus presentations.

Data Analyses

Recall scores were based on the proportion of words correctly recalled for each condition within each list. For the 1P condition, this proportion was based on the nine 1P words in the functional list. The 2P and 1P' scores associated with lags of 0, 4, and 8 were proportions of the three words exemplifying each combination.

To measure HR, the R-waves on the EKG recorded on magnetic tape were converted into digital pulses, and R-R intervals were read to the nearest millisecond by the PDP-8. These data were subsequently converted into rate in beats per minute per 1 sec period for 1 sec before and 5 sec after stimulus presentation. Thus, 6 sec of HR were obtained for each of the 36 presentation events in the functional list. Since there were no 1P words uniquely associated with each lag value, HR responses to these items were not considered in the data analysis. Given the random assignment of stimulus words to presentation events, it was assumed

that the response to 1P words would be equivalent to those responses evoked by P1 of repeated words. In addition, HR responses to P1, P2, and 1P' presentations were each formed into two trial blocks representing halves of the session.

The primary method of examining the HR data was by analysis of the variance of orthogonal components of trend over the 6 sec of data scored. This type of analysis is not greatly affected by differences in prestimulus level (Graham & Jackson, 1970). Such differences were not tested for, and HR scores were not adjusted for regression on prestimulus values. For convenience, however, illustrations display HR curves as differences from prestimulus level.

Several important points should be noted about the HR analyses used throughout this paper. First, the trend analysis program contained provision for only a limited number of factors. As a result, factors of minimal interest were eliminated from the HR analyses. These same limitations often resulted in a necessity for combining two factors into a single effect. Second, the program allowed for the computing of planned comparisons on several factors. Effects of primary interest for this research were evaluated in such a manner. Third, when planned comparisons were employed, the program generated only a pooled error term. Since this situation results in the inflation of the degrees of freedom associated with an effect, a conservative F test using reduced degrees of freedom was initially employed for all comparisons (Geisser & Greenhouse, 1958). If the conservative test for a comparison of primary interest was marginally significant, and an F test using unreduced degrees of freedom was statistically significant ($p < .05$), then the unpooled error term for that comparison was derived, and the F was

tested with the normally associated degrees of freedom. In short, where computer program limitations in the calculation of important planned comparisons left the significance of an effect in doubt, calculations were performed to determine the exact and appropriate F value. Comparisons resulting in such a situation can be identified by noting the inclusion of the MSE where they are referred to in the text.

Results

Recall

The main results of the experiment are illustrated in Figure 1. In addition to the probability of recall of 1P words, recall of 2P and 1P' words are shown as a function of lag. A repetition effect is apparent. Recall of 2P words at all lags was greater than recall of 1P words. Additionally, recall of 2P words increased as a function of lag. The large increase between Lag 0 (i.e., MP) and Lags 4 and 8 reflects a distribution effect. An analysis of 2P recall scores (Appendix B, Table 1) revealed a significant main effect of lag, $F(3,30)=8.61$, $p < .001$, while neither the main effects of list type or list number nor their interaction with the lag factor were significant. To facilitate comparison of 1P and 2P conditions, 1P was included as a level of the lag factor. A Duncan New Multiple Range Test disclosed that recall of 2P words at Lag 4 and Lag 8 was significantly greater than recall of 1P words and 2P words at Lag 0 ($p < .05$). No other pairwise comparisons were significant. Although the difference was not significant, it should be noted that an increase of .16 in recall probability occurred between 1P and 2P at Lag 0.

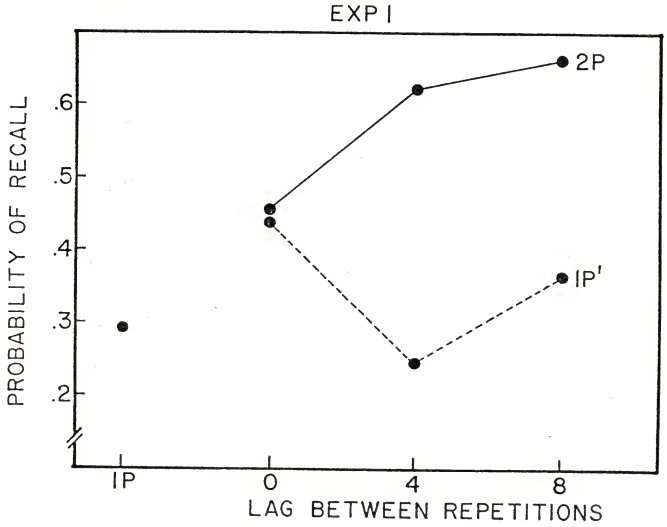


Figure 1. Experiment 1: Mean probability of recall for single presentation words (1P), repeated words (2P), and single presentation words immediately following repetitions (1P') as a function of the lag between repetitions.

A complementary analysis was performed for 1P' recall scores (Table 1). The main effect of lag was only marginally significant, $F(3,30)=2.71$, $p < .07$. Again, neither the effects of list type or list number nor their interaction with lag were significant. The prediction that recall of 1P' words would be a decreasing function of lag was partially supported by a Duncan Test, which revealed that recall probability for 1P' words at Lag 0 was significantly greater than that for 1P' words at Lag 4 ($p < .05$). No other pairwise comparisons were significant. Although recall probability for 1P' words increased between Lag 4 and Lag 8, a distribution effect is suggested by the overall superiority of recall for 1P' words at Lag 0.

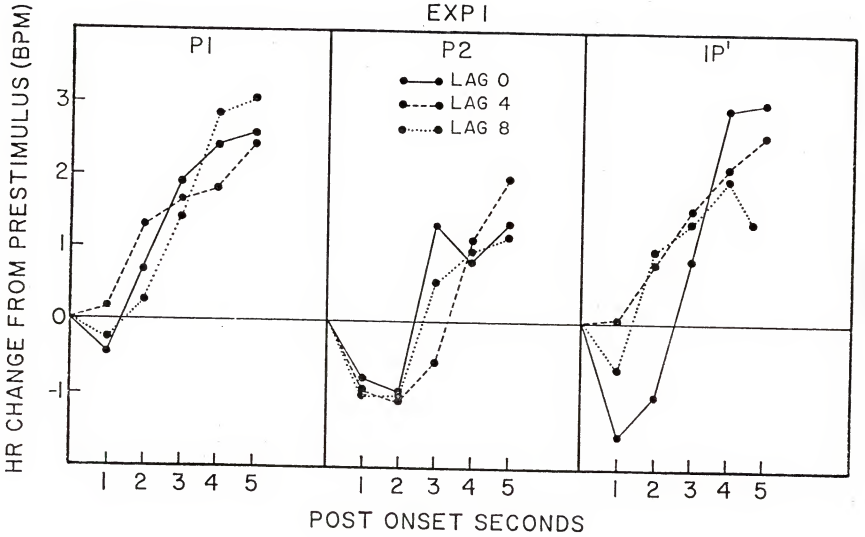
Heart Rate

The HR responses evoked by P1, P2, and 1P' word presentations are illustrated in Figure 2. Each curve is the average of 72 individual curves, 6 per subject. Complete HR analyses can be found in Appendix C (Tables 2-4).

The biphasic nature of the HR response, a brief deceleration followed by a linear acceleration, is apparent from Figure 2. Separate analyses were performed for comparing P1-P2 and P1-1P' responses (Table 2), and the biphasic pattern was confirmed by both the combined P1-P2 HR responses (seconds $F(5,50)=17.79$, $p < .001$; linear seconds $F(1,10)=84.08$, $p < .001$; cubic seconds $F(1,10)=12.11$, $p < .01$) and the combined P1-1P' HR responses (seconds $F(5,50)=21.15$, $p < .001$; linear seconds $F(1,10)=76.90$, $p < .001$; cubic seconds $F(1,10)=11.77$, $p < .01$).

There was a tendency for greater HR deceleration to occur in response to P2 than to P1, independent of lag. Planned comparisons

Figure 2. Experiment 1: Mean heart rate change in beats per min for 5 sec following stimulus presentation plotted as differences from a 1 sec prestimulus baseline. Curves represent responses to the first (P1) and second (P2) presentation of repeated words and to the presentation of words immediately following repetitions (1P') as a function of the lag between repetitions.


EXP I
P1
P2
IP'
LAG 0
LAG 4
LAG 8
HR CHANGE FROM PRESTIMULUS (BPM)
3
2
1
0
-1
1 2 3 4 5
1 2 3 4 5
1 2 3 4 5
POST ONSET SECONDS

revealed an overall difference between P1 and P2 only for the quadratic trend across seconds [$F(1,10)=5.33$, $MSE=.70$, $p < .05$], a result of the greater deceleration evoked by P2. The linear seconds trend did not vary between P1 and P2, and there was no indication of differential responding to either P1 or P2 as a function of lag. Pooled HR response curves for P1 and P2 are displayed in Figure 3. Two-tailed paired-t tests for each second, including the prestimulus second, disclosed a significant difference in HR only for second 2 ($t(11)=3.82$, $p < .01$). In addition, the peak HR deceleration (or least acceleration) occurring within the first 2 poststimulus seconds was greater for P2 than P1, $t(11)=3.39$, $p < .01$.

Responses to 1P' presentations did vary as a function of lag (see Figure 2, right-hand panel). Planned comparisions did not reveal any differences in the overall HR trends between P1 and 1P'; however, a significant P1-1P' x linear lag x cubic seconds interaction [$F(1,10)=5.41$, $p < .05$] suggested that some differential responding to P1 and 1P' had occurred. Subsequent comparisons disclosed that this interaction was manifested primarily by a difference in the cubic seconds trend between P1 and 1P' at Lag 0 [$F(1,10)=6.66$, $MSE=2.30$, $p < .05$], reflecting the greater HR deceleration evoked by 1P' presentations. An analysis of HR responses to 1P' presentations as a function of lag (Table 3) resulted in a marginally significant lag x cubic seconds interaction, $F(2,20)=2.90$, $p < .10$. Planned comparisons revealed a difference only in the cubic seconds trend between 1P' at Lag 0 and Lag 4 [$F(1,10)=5.77$, $p < .05$], indicative of the tendency for a relatively large deceleration to occur at Lag 0 but not at Lag 4. One-tailed paired-t tests for each second resulted in only a marginally significant difference in

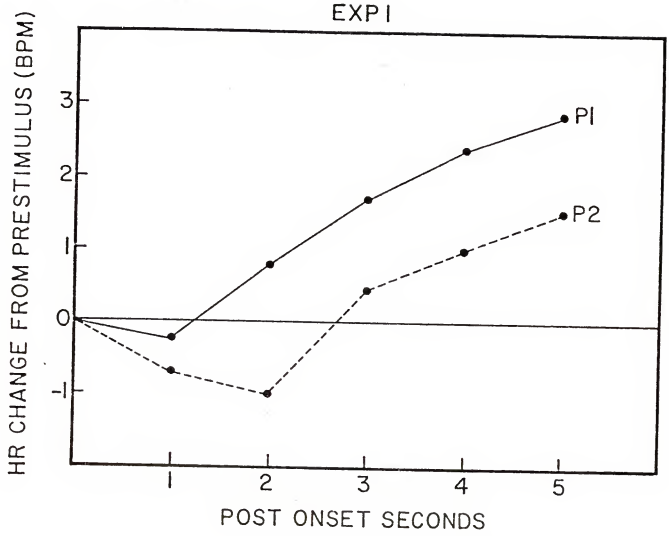


Figure 3. Experiment 1: Mean heart rate change in beats per min for 5 sec following stimulus presentation plotted as differences from a 1 sec prestimulus baseline. Curves represent responses to the first (P1) and second (P2) presentation of repeated words averaged across lags.

the first poststimulus second, $t(11)=1.62$, $p < .10$. Although the magnitude of HR deceleration evoked by 1P' presentations was not a decreasing function of lag, the difference between Lag 0 and Lag 4 was in the appropriate direction. In addition, the fact that 1P'-evoked HR deceleration was much larger at Lag 0 than at either Lag 4 or Lag 8 is in accord with a distribution effect.

Two additional features of the HR data are worth noting. First, the linear seconds trend, indicative of rehearsal-related HR acceleration, clearly accounted for most of the variance in the second-by-second changes in HR. However, no comparisons involving the linear trend approached statistical significance. Those differences in the HR response which did occur were all apparently related to the initial deceleratory component. Second, there were no consistent changes in the HR response between trial blocks (i.e., halves of the session). Separate analyses of P1, P2, and 1P' HR responses as a function of trial blocks (Table 4) revealed no trial blocks x seconds interactions for any of the three presentation types.

Discussion

The effects of repetition, distribution, and lag on the LTM for 2P words were all prominent in the free-recall data. These results are very much in accord with the findings of Melton (1967) and Madigan (1969), and also extend the generality of the effects to presentation rates as slow as 10 sec per item. In addition, the shape of the lag function for 2P words and the recall probability for 1P words in the present experiment were almost identical to those reported by the

earlier studies. Of course, this is considering only the range of lag values which were common to all three studies. An important discrepancy between studies, however, occurred for the difference in recall probability for 1P words and 2P words at Lag 0. For example, Madigan (1969) found this difference to be on the order of about .03, while in the present experiment there was an increase of .16 in recall probability between 1P and 2P at Lag 0. The results of the present experiment exhibited a greater overall effect of repetition, independent of the influence of distribution or lag (i.e., the entire lag function was shifted toward greater recall probability).

This discrepancy between experiments is not surprising when the conditional probabilities of a given word being repeated are considered. In the Melton (1967) and Madigan (1969) studies this probability was .50, but in the present experiment it was only .21. Thus, in the present experiment a repetition was a much more infrequent or isolated event, which may have resulted in more attention being devoted to P2 presentations. Given this situation, the fact that the distribution and lag effects remained unattenuated is of great interest.

Several other experiments, in which the amount of attention devoted to repetitions was manipulated by instructions to subjects, motivational incentives, or distinguishing physical characteristics of repeated stimuli, have reported similar findings. For example, Hintzman et al. (1975) presented scenic pictures to subjects with lags of 0, 1, 5, and 15 intervening items between P1 and P2. Half of the P2 presentations at each lag were accompanied by a tone, which was a signal to subjects that the item would be worth money on a remote retention test. The retention measure was frequency judgment, and it

was found that repeated pictures for which the tone accompanied P2 were judged to have a higher mean frequency of occurrence than repeated pictures with no tone at P2. The improvement in retention under the tone condition occurred at all lags, the major result being that the tone manipulation shifted the whole lag function toward a higher mean frequency judgment with virtually no effect on the shape of the lag function. Elmes et al. (1973) employed a design in which MP and DP of repeated words was varied between lists. Some lists were presented in the visual mode and others in the auditory mode, but the critical manipulation was that P2 of some repeated words was isolated by being presented in a distinctive way, a distinctive voice in auditory lists or distinctive letters in visual lists. The major important finding was that isolation of P2 produced overall better recall of repeated words, but the distribution effect was not attenuated at all.

Forcing greater attention to repetitions via instructions, incentives, or isolation of the physical attributes of a stimulus enhances the repetition effect but does not influence the effects on the spacing of repetitions. The results of the present experiment extend these findings to include event uncertainty as an attentional factor which manifests itself only in the overall effectiveness of repetition. Apparently, the effects of repetition and spacing are at least partially independent.

Recall probability for 1P' words showed a marked reciprocal relation to the distribtuion effect found for the recall of 2P words; however, unlike the findings of Elmes et al. (1972), there was an upturn in recall for 1P' words at the longest lag. Although Elmes et al. (1972) found that recall for words immediately following repetitions

was inversely related to lag (lags of 0, 3, and 10 were used), their data showed that the decrease in recall between Lag 3 and Lag 10 was minimal compared to the large decrease found between Lag 0 and Lag 3. There were several methodological differences between the Elmes et al. (1972) study and the present experiment, but none of these offer any obvious account for the discrepancy in recall performance at long lags. In addition, it is doubtful that this discrepancy was due to an artifact of item selection in the present experiment since there was no evidence that the different word lists influenced the results. Despite the disagreement at the longest lag, the observed reciprocity in recall for 2P and 1P' words in conjunction with the distribution effect strengthens the hypothesis that a compensatory allocation of spare processing capacity is applied to stimuli immediately following massed presentations.

The HR results revealed several important findings. First, the HR response evoked by the word presentations was biphasic, as anticipated. The initial deceleratory component and the subsequent linear acceleration appeared to reflect different stages in the processing of the stimulus words: attention and rehearsal, respectively. The form of the HR response was very similar to that found in an experiment by Tursky et al. (1970), in which subjects were presented a string of digits to be rehearsed and transformed. During the period of presentation of the digit strings there was a marked HR deceleration, indicative of attentional processes. A linear increase in HR followed as the digits were rehearsed.

Second, contrary to predictions, the enhanced recall as a function of lag was not accompanied by corresponding HR changes. The magnitude

of HR deceleration evoked by P2 remained constant across lag conditions. However, the response to P2 was larger than to P1, a finding which appears to be consistent with the enhanced repetition effect evident in the recall for 2P words. Since the uncertainty associated with the occurrence of a repetition apparently influenced the recall of 2P words via increased attention to repetitions, it is reasonable that such increases in attention would have an effect on the HR response. Uncertainty and novelty are fundamental to the elicitation of orienting (Sokolov, 1963), and this response is frequently accompanied by a robust HR deceleration (Graham & Clifton, 1966). Thus, increased attention or the elicitation of the orienting response as a result of uncertainty may have obscured any HR-indexed differential processing of P2 presentations.

Third, HR responses to 1P' did vary as a function of lag and complemented the recall for 1P' words. The larger HR deceleration to 1P' presentations at Lag 0 than at either Lag 4 or Lag 8 was coincident with the greater overall recall probability for 1P' words at Lag 0. In fact, recall probability for 1P' words was directly related to the magnitude of HR deceleration evoked by 1P' at each lag. The only explanation for these results is that some differential attentional capacity was devoted to P2 presentations as a function of lag. Differences in attention to P2 were reflected in the recall probability for repeated words but not in the P2-evoked HR response for reasons already mentioned. Reciprocal allocations of spare attentional capacity to 1P' as a function of distribution were evident both in the recall for 1P' words and in the magnitude of HR deceleration to 1P' since the HR response to these presentations was not directly affected by isolation or strong uncertainty effects.

The results of Experiment 1 have shown that attentional processes are related to the effects of repetition and distribution on memory. The ability of the HR response to reveal variations in attention to stimuli in a basic memory task as well as to differentiate attentional and rehearsal processes was most encouraging. The relationship between attentional processes and repetition and distribution effects could be clarified by measuring recall and HR in a paradigm which minimizes the isolation or uncertainty of repetitions. This was the basic rationale behind the second experiment.

EXPERIMENT 2

The second experiment employed a between-list manipulation of distribution (MP vs. DP). In addition, a patterned scheduling of repetitions under each distribution condition was incorporated in an attempt to further reduce the uncertainty associated with the occurrence of P2. It was predicted that by reducing uncertainty, differences in attention to P2 as a function of the proximity of P1 would become apparent. The experimental design also allowed for the replication of the previously demonstrated relationship between recall and HR deceleration for 1P' presentations.

The occurrence of a larger HR deceleration to P2 under distributed than under massed presentation conditions, if accompanied by a corresponding difference in recall for repeated words, would provide strong evidence for an attentional explanation of distribution and spacing effects. If recall and HR deceleration for 1P' presentations were found to be inversely related to distribution, as in Experiment 1, then this would strengthen the position that compensatory allocations of attentional capacity to nearby stimuli are a consequence of the differential processing of repetitions. An additional measure of phasic arousal, the skin resistance response, was recorded to provide supplementary data relevant to the processing of repeated stimuli.

Method

Subjects

Five males and seven females were drawn from the same source and satisfied the same criteria required in the first experiment. Subjects ranged in age from 17 to 21 years with a mean of 19.8 years. Three additional subjects were replaced: one for an unusually high basal skin resistance level outside the calibration range of the recording equipment, one for failure to give scoreable skin resistance responses, and one due to experimenter error.

Stimulus Lists and Design

The stimulus words were the same as those used in Experiment 1. Each word list (A - B) was used to construct two lists of 52 presentation events consisting of 26 1P words and 13 2P words. The two presentation lists differed in that repetitions were massed in one (lag 0) and distributed in the other (lag 4). This yielded a total of four presentation lists: one MP and one DP list for each set of words.

Eight-event primacy and recency buffers were composed of four 1P words and two 2P words. The buffers were not included in any data tabulations of analyses. Within each 36-event functional presentation list were 9 1P words occupying 9 positions, 9 2P words occupying 18 positions (9 P1 and 9 P2 presentations), and 9 1P' words occupying the 9 positions immediately after each repetition. The MP and DP lists constructed from the same set of words were isomorphic with respect to individual 1P, 2P, and 1P' items.

There was a patterned scheduling of repetitions for each distribution condition. The pattern was continuous throughout both the buffers and the functional presentation list and always began with the occurrence of the first repetition. For the MP lists, every fourth presentation event was a repetition. The pattern was somewhat more complex for the DP lists in that repetitions alternated between every third and fourth presentation event. The average serial positions of each type of presentation within the functional MP lists were: 1P=28.0, 2P=26.0, and 1P'=27.0. For the functional DP lists these were 23.7, 28.8, and 29.8, respectively. The conditional probability of any given word being repeated was .33 for all lists. While this represents only a small increase in probability over that in Experiment 1 (.21), manipulating distribution between lists and the highly predictable ordering of repetitions resulted in a considerable reduction of event uncertainty within the paradigm.

Subjects were each presented and subsequently recalled one MP and one DP list. The ordering of distribution conditions (MP - DP) and the ordering of words lists (A - B) were both counterbalanced across the 12 subjects. Thus, the effects associated with the two counterbalanced orderings constituted two crossed, between-subjects factors. Distribution was a within-subjects factor, and presentation type varied within both MP-DP lists and subjects.

Apparatus

The appartus was essentially the same as that used in the first experiment, with the addition of components required for the electrodermal measure. Skin resistance was monitored via Beckman Biopotential

electrodes (Ag-AgCl, effective diameter=.62 cm) in a bipolar configuration: the two active sites being located on the volar survace of the middle segment of the index and middle fingers. These sites were cleansed with alcohol, masked with Beckman double-faced adhesive collars, and after the electrodes were positioned, the entire preparation was very loosely bound with micropore tape. The electrode medium was Johnson's K-Y surgical jelly, a compound in which the conducting electrolyte is NaCl in a concentration approximately that of human sweat (Edelberg, 1967). A constant current was imposed through the electrodes by a Beckman Type 9842 GSR coupler adjusted to provide a current density of 8$\mu A/cm^2$. The coupler provided parallel directly-coupled output voltages to adjacent channels of the Beckman polygraph. One channel was used for the basal skin resistance recording, and the other, set for a higher sensitivity and 3-sec time constant, processed and amplified the phasic response. Both the basal skin resistance level and the phasic response were recorded on the paper records provided by the polygraph.

Procedures

The general procedures from Experiment 1 required only slight modification to accommodate the second experiment. These changes were related to the addition of the skin resistance measure and to the patterned ordering of repetitions within the presentation lists. Instructions to subjects were modified to include the following: (a) subjects were told that electrodes would be attached to two fingers of their non-preferred hand; (b) additional emphasis was placed on the restriction of movements during the list presentations, and subjects

were especially cautioned about the flexing or tapping of those fingers to which the skin resistance electrodes were attached; (c) the patterns of repetition for the MP and DP lists were carefully explained to each subject just prior to the respective list presentation.

Data Analyses

Recall scores were based on the proportion of words correctly recalled for each presentation type within the functional MP and DP lists. This proportion was based on nine words for 1P, 2P, and 1P' presentations under each distribution condition.

As in the first experiment, 6 sec of HR were obtained for each of the 36 presentation events within the functional lists. However, there were three major differences in the HR analyses for the present experiment. First, the between-list manipulation of distribution permitted the HR responses to 1P presentations to be included in the data analyses, an obvious advantage being that HR responses to singly presented words and P1 of repeated words could be directly compared. Second, in some analyses the change in cardiac responses across trial blocks was examined. For these cases, the responses to each presentation type were formed into three blocks of three trials each. Third, and most important, was that the HR response was broken down into two components which were separately analyzed: the attention-related change in HR between the prestimulus second and first poststimulus second, and the rehearsal-related HR trend across the five poststimulus seconds. In addition, prestimulus HR levels were also analyzed to determine if any initial level effects influenced the subsequent response.

Skin resistance levels and responses were read from the paper polygraph records in millimeters and converted to kilohms. Base levels were taken as that reading prevailing at the time of stimulus onset. Phasic responses were scored as the first downward pen deflection beginning between 1 and 4 sec after stimulus onset. In the case of compound responses, the scoring conventions recommended by Edelberg (1967) were adopted. Both measures were rounded to the nearest half millimeter and were scored blindly with respect to experimental manipulations. Subsequently, the basal and phasic resistance measures were respectively transformed into skin conductance level and skin conductance change (i.e., skin conductance response, SCR). The switch to conductance units (μmhos) was made since there is considerable physiological and statistical justification for use of the latter scale (Edelberg, 1967).

Skin conductance levels and SCRs for each presentation type within the functional lists were formed into trial blocks in a manner analogous to the treatment of the HR data. This allowed for the analysis of changes in the SCR across trial blocks and also tended to minimize the number of zero data points. Response scores were not adjusted for initial level since the pooled linear coefficient for the regression of the SCR on skin conductance level (.01) accounted for only about 5% of the variance in the SCR. No substantial initial level effects were expected because the conversion from resistance to conductance change contains a built-in correction for base-level resistance (Edelberg, 1967). Minimal relationships between initial level and the SCR have been previously reported (e.g., Jackson, 1974; Lacey & Siegel, 1949) and were not investigated further in the present paper.

Results

Recall

The probabilities of recall for 1P, 2P, and 1P' words as a function of distribution are presented graphically in Figure 4. A prominent effect of distribution is evident in the recall for both 2P and 1P' words. Recall for 2P words was much higher under the distributed than under the massed distribution condition. The relationship between recall and distribution was reversed for 1P' words, although the magnitude of the effect was smaller. Recall for 1P words showed little variation as a function of distribution.

An analysis of recall scores (Appendix D, Table 5) revealed a significant main effect of presentation type [$F(2,16)=3.69$, $p < .05$] and a significant distribution condition x presentation type interaction, $F(2,16)=12.90$, $p < .001$. A Duncan Test on the main effect of presentation type indicated a reliable difference in recall only between 1P and 2P words ($p < .05$), and this was primarily due to the high probability of recall for 2P words in the distributed presentation condition. Additional pairwise comparisons on the interaction between distribution condition and presentation type disclosed significantly greater recall for 2P words under the DP condition than for any other factorial combination ($p < .05$). Recall for 1P' words in the massed condition was significantly greater than that for 1P or 1P' words under the distributed condition ($p < .05$). The finding of primary interest, of course, was that distribution had opposite and reliable effects on the probability of recall for 2P and 1P' words.

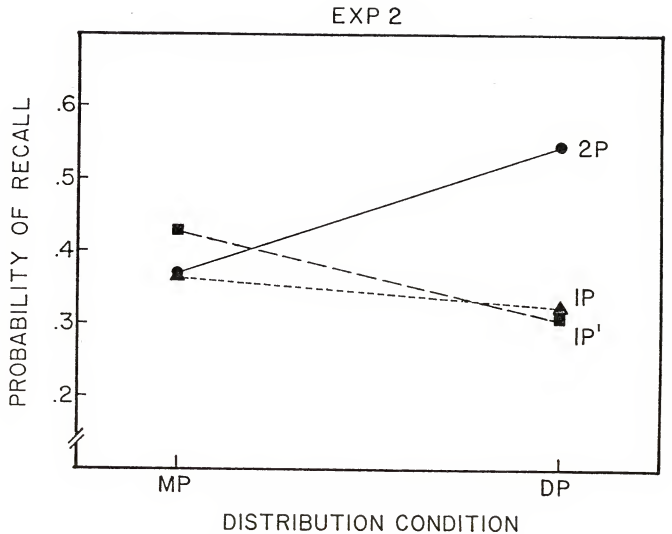


Figure 4. Experiment 2: Mean probability of recall for single presentation words (1P), repeated words (2P), and single presentation words immediately following repetitions (1P') as a function of distribution condition.

It may be noted from Table 5 that a high-order interaction involving the condition order and list order factors was statistically significant [$F(2,16)=6.71$, $p < .01$], and probably reflected some complex combination of subject and item effects. However, this source of variance cannot account for the main results of the experiment.

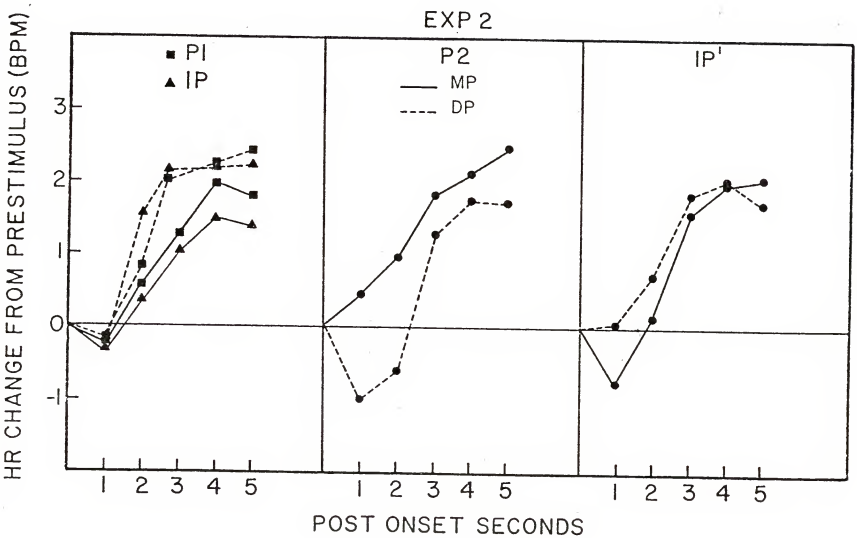
Heart Rate

The HR responses evoked by all presentation types as a function of distribution condition are illustrated in Figure 5. Each curve is the average of 108 individual curves, 9 per subject. While the results of principal interest were examined by means of planned comparisons, the complete HR analyses can be found in Appendix E (Tables 6-8).

As in Experiment 1, the cardiac responses were predominantly biphasic; however, the initial deceleratory component was significantly altered or eliminated in several instances. The change in HR between the prestimulus second and first poststimulus second was differentially affected by distribution in the case of P2 and 1P' presentations (see Figure 5, center and right-hand panels). For the P2 comparison, the tendency for an initial HR deceleration to occur under the distributed but not under the massed condition was significant, $F(1,10)=9.89$, $p < .05$). The presence of a P1-P2 x distribution condition interaction [$F(1,10)=5.2$, $p < .05$] further reflected the difference in the initial P2 response component as a function of distribution.

Distribution had a reversed effect on the 1P' responses in that deceleration occurred only in the MP condition, $F(1,10)=8.06$, $MSE=.30$, $p < .05$. There were no effects of distribution on the deceleratory response component to either 1P or P1 presentations nor were there any differences between the 1P

Figure 5. Experiment 2: Mean heart rate change in beats per min for 5 sec following stimulus presentation plotted as differences from a 1 sec prestimulus baseline. Curves represent responses to single presentation words (1P), first (P1) and second (P2) presentations of repeated words, and single presentation words immediately following repetitions (1P') as a function of distribution condition (MP - DP).


EXP 2
PI
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HR CHANGE FROM PRESTIMULUS (BPM)
3
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1 2 3 4 5
1 2 3 4 5
POST ONSET SECONDS

and P1 responses (all $\underline{F}$s < 1). An additional point of interest is that the rehearsal-related change in HR across the five poststimulus seconds was highly significant [seconds $\underline{F}(4,40)=16.60$, $\underline{p} < .001$; linear seconds $\underline{F}(1,10)=29.24$, $\underline{p} < .001$; see Table 6], but no comparisons involving this component of the HR response approached statistical significance.

Heart rate responses to the four presentation types were also analyzed separately within each distribution condition. For the MP condition, the only significant comparison was between P2 and 1P' in the initial response component, $\underline{F}(1,10)=8.91$, $\underline{p} < .05$. Accordingly, analysis of the DP condition revealed only a marginally significant P2-1P' comparison for HR change between the prestimulus second and first poststimulus second, $\underline{F}(1,10)=3.83$, $\underline{MSE}=2.41$, $\underline{p} < .10$. No other comparisons for either distribution condition were reliable. In addition, there was no indication that the HR response to any presentation type changed across the three trial blocks (see Tables 7 and 8).

Differential cardiac responses to P2 and 1P' presentations were not attributable to differences in prestimulus HR levels. An analysis of cardiac rates in the prestimulus second (Table 6) disclosed no differences between the eight presentation type x distribution condition combinations ($\underline{F} < 1$). There was, however, some interaction with the between subjects factor of condition order [$\underline{F}(7,70)=5.88$, $\underline{p} < .01$], but this was primarily due to differences in prestimulus HR levels between the two groups of subjects.

Skin Conductance

Average SCR amplitudes as a function of presentation type and distribution condition are graphically presented in Figure 6.

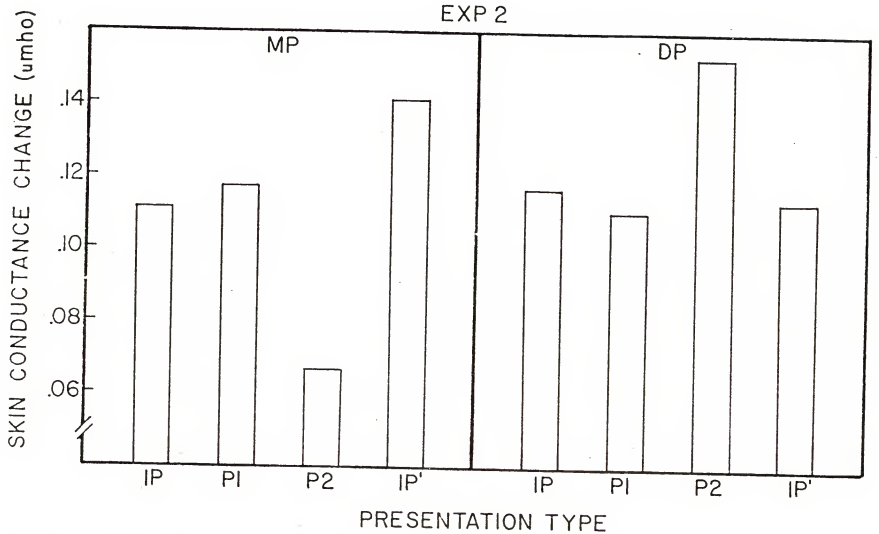


Figure 6. Experiment 2: Mean skin conductance change in micromhos following stimulus presentation. Bars represent responses to single presentation words (1P), first (P1) and second (P2) presentations of repeated words, and single presentation words immediately following repetitions (1P') as a function of distribution condition (MP - DP).

Distribution had a pronounced effect on the amplitude of P2-evoked responses: The responses to P2 under the massed condition were markedly smaller than those for the distributed condition. For the 1P' presentations, response amplitude was higher under the MP condition than under the DP condition. Skin conductance response amplitude for 1P and P1 presentations showed little variation as a function of distribution.

To determine the reliability of these effects, an analysis of the variance in SCR scores was performed (Appendix F, Table 9). The interaction between presentation type and distribution condition was significant [$F(3,24)=5.86$, $p < .01$] and was subsequently analyzed via a Duncan Test. Pairwise comparisons revealed that within the massed condition the P2 response was smaller than either the P1 or 1P' responses ($p < .05$). Additionally, the P2-DP response was reliably larger than the P2-MP response ($p < .05$). The presence of a marginally significant trial blocks effect [$F(2,16)=3.39$, $p < .10$] reflected a slight tendency for SCR amplitude to decrease across the list presentation; however, no interactions of the trial blocks effect with either presentation type or distribution condition approached significance.

The major important finding was that SCR amplitude for P2 presentations was reliably affected by the distribution between repetitions. Although the effect of distribution on 1P' response amplitude was not significant, the fact that 1P' responses were larger under the massed than under the distribution condition is clearly in accord with the predicted outcome of the experiment. Thus, the skin conductance results are in good agreement with both the HR and recall data.

From Table 9, it may be noted that two additional interactions achieved statistical significance. The first was the interaction of

condition order and distribution condition [$F(1,8)=7.75$, $p < .05$], and the second involved the combination of list order and presentation type, $F(3,24)=4.28$, $p < .05$. Pairwise comparisons between the means for the first interaction produced no significant differences, a situation suggesting that some linear combination of the means was responsible for the overall significant effect (Kirk, 1968). The list order x presentation type interaction was primarily due to differences in the overall responsiveness between the two groups of subjects comprising the list order factor, since only one mean violated this pattern. The major skin conductance results were not attributable to either of these sources of variance.

Discussion

The results of Experiment 2 were clear--distribution had pronounced effects on the long-term recall for repeated words and words immediately following repetitions, and these effects were apparently related to concomitant, systematic variations in both the cardiac and skin conductance responses.

Recall probability for repeated words in the DP condition was at a level approximating that which would be expected from two independent presentations (Waugh, 1963). In contrast, massed presentation of repetitions resulted in no improvement in the recall for repeated words over singly presented words. Subjects obviously derived very little benefit from seeing an item twice under the MP schedule. Underwood (1969) reported quite similar findings using comparable stimulus materials and a between-list manipulation of distribution. He proposed,

as one explanation of the distribution effect, that subjects do not attend to or rehearse P2 effectively when repetitions are massed.

Distribution had a reciprocal effect on the probability of recall for words immediately following repetitions. Recall for 1P' words in the MP condition was greater than recall for 1P' words in the DP condition. This finding is in accord with both the results of Experiment 1 and those of Elmes et al. (1972). The claim that allocations of spare processing capacity, modulated by the variable processing demands for repeated stimuli, are responsible for this effect is worthy of serious consideration. The psychophysiological data did, in fact, support this contention.

In the present experiment the uncertainty associated with the occurrence of a repetition was reduced, and the overall facilitory effects of stimulus isolation on recall and HR deceleration were apparently eliminated. As a result, differential processing of both P2 and 1P' presentations as a function of distribution was evident in the cardiac responses. Moreover, these differences were manifested primarily in the decelerative component of the response, indicative of a change in attention to external events. In this respect the changes in the HR response were similar to those observed in the first experiment. There was a marked cardiac deceleration to P2 under the distributed schedule; however, the P2-evoked response when P1 and P2 were presented successively consisted only of a linear acceleration. Since the HR response in this task is multiply determined by an attention-related tendency toward deceleration and a rehearsal-related tendency toward acceleration, this latter result is indicative of a lack of attention to P2 when repetitions are massed.

The 1P' cardiac response showed a reversed effect of distribution: a relatively large cardiac deceleration to 1P' under the massed condition and only an accelerative response when repetitions were distributed. The reciprocal relationship between the P2 and 1P' responses strongly supports the spare capacity explanation for the effects of distribution on stimuli immediately following repetitions. As such, the pattern of of HR results found in the present experiment precisely fit the predictions of an attentional explanation of distribution and spacing effects.

The results for the SCR were the image of those for the cardiac response. Differential processing of P2 presentations was evident. The effect of distribution on the 1P'-evoked SCRs was in the expected direction in that 1P' response amplitude was greater for the massed than for the distributed presentation condition; however, this difference was not statistically reliable.

One curious phenomenon which appeared in both the cardiac and skin conductance data was the tendency for the P2 response under the distributed presentation schedule to be larger than the P1 response. Although this tendency was not statistically significant for either response measure, it demands at least some attempt at explanation. One possibility is that the pattern of repetitions in the DP condition produced enough event uncertainty to cause a repetition effect similar to that found in Experiment 1. This seems unlikely, however, since the pattern of repetition in the DP condition was only slightly more complex than the MP pattern, and both patterns were carefully explained to subjects just prior to the list presentation. Another possible explanation is based on the fact that in the DP condition (i.e., a lag of four intervening items) a repetition occurred after a number of

intervening items which is close to the capacity of STM (e.g., Craik, 1971; Murdock, 1967). This situation could have resulted in a greater ambiguity or uncertainty associated with the recognition of P2 as a repetition and therefore may have required more attentional capacity. At the extremes of distribution, a massed schedule and a distributed schedule with a greater lag between repetitions, the identification of a repetition would be highly probable in the first case while in the latter case a repetition would become increasingly more like a single presentation event. Such an explanation seems consonant with the U-shaped lag function for the recall of 1P' words and 1P'-evoked cardiac deceleration found in Experiment 1.

The critical question as to whether the second presentation of a repeated item is deficiently processed when repetitions are massed was unequivocally answered in the affirmative. Recall for repeated words under the MP schedule was no better than for single words. The HR response to both 1P and P1 presentations consisted of the familiar biphasic pattern; however, the response to P2 under the massed schedule was solely accelerative. In addition, the SCR to P2 was markedly and reliably smaller in amplitude than either the 1P or P1 response. An interesting bit of supportive evidence has been provided by Posner, Buggie, and Summers (1971) using a letter-matching task. These researchers have found that components of the vertex evoked potential occurring from 200-250 msec after the second letter is presented were reduced in amplitude when that letter was a repetition. Since there is considerable data indicating that these late components of the vertex evoked potential are related to selective attention (e.g., Donchin & Cohen, 1967; Smith, Donchin, Cohen, & Starr, 1970), the findings of

Posner et al. (1971) are complementary to the results of the present experiment.

Several additional points relevant to the cardiac and skin conductance data are worthy of mention. The failure of the P1-P2 difference for the initial HR response component to achieve statistical significance is probably attributable to the inherent complexity and associated variability of the cardiac response (Graham, 1973; Kahneman, 1973). Perhaps increasing the number of subjects or trials would have resulted in greater reliability. In contrast, exosomatic electrodermal responses are simpler, unidirectional changes (e.g., Edelberg, 1967) and do not reflect the differences between external and internal processing (Kahneman, 1973; Lacey et al., 1963). The SCRs in the present experiment may thus be viewed as an undifferentiated index of processing capacity. However, given that the HR changes in the present experiments occurred only in the initial attention-related component and the Tursky et al. (1970) finding that skin conductance was not particularly sensitive to maintenance rehearsal, it is suggested that variations in SCR amplitude were primarily reflecting changes in attentional processes.

The present experiment has provided supportive evidence for the following propositions regarding the effects of distribution and spacing on memory: (a) the locus of differential processing of repeated stimuli is at the second presentation of the stimulus; (b) under conditions of massed presentation a repeated stimulus is deficiently processed such that LTM for that stimulus derives little or no benefit from the repetition; (c) compensatory allocations of spare or leftover processing capacity are applied to stimuli immediately following

repetitions, and therefore LTM for these stimuli depends upon the amount of processing capacity required by the preceeding repetition; (d) differential processing involves variations in the amount of attention devoted to a stimulus.

As noted earlier in this paper, differences in the amount of rehearsal an individual stimulus receives would probably not be detectable in the present studies. It was also suggested that differential rehearsal of repetitions and the stimuli immediately following was a possible and perhaps probable consequence of distribution and spacing effects, and that attention-related and rehearsal-related variations in processing were complementary rather than antagonistic explanations of the same phenomena. In all fairness to consolidation and rehearsal theories which predict that the presentation of P2 disrupts the memory consolidation or rehearsal of P1, it must be admitted that although there is little evidence to support such disruptions as a cause of poor LTM for closely spaced repeated stimuli, they too would not be discernible within the present experiments.

A basic question about the parameters which determine the effectiveness of repetition remains to be answered. This question concerns whether differential processing of repetitions is primarily a function of the time or the number of intervening items between P1 and P2. Hintzman (1974, 1976) has suggested that the time between presentations appears to be the critical parameter. To support this claim, he has argued that the most consistent finding across paradigms, retention tests, and stimulus materials is that LTM for repeated stimuli increases as the time between P1 and P2 increases up to approximately 15 sec or so. While this survey of previous research is certainly correct, it is also

true that the time between repetitions has almost invariably been determined by the number of intervening stimuli and the presentation rate (typically presentation rates of 2-3 sec per item have been employed). Thus, previous research provides little data to differentiate temporal effects from interference or displacement effects.

In the present experiment, LTM for repeated words under a massed presentation schedule was no better than for single words even when 10 sec separated P1 and P2. Additionally, the psychophysiological data revealed a lack of attention to P2 under the massed schedule. Underwood (1969) reported similar results with a presentation rate of 5 sec per item. Perhaps the relative importance of time or number of intervening stimuli depends on the type of stimulus materials used. When stimuli which are easily rehearsed are used, such as the verbal materials in the present studies, displacement or interference may place a greater role than the passage of time. This seems consistent with the Bjork and Allen (1970) finding that interpolating a difficult task between P1 and P2 results in better long-term retention of repetitions. The guiding principle may be similar to the one proposed by Glanzer (1969, 1972), which basically states that P2 will not be entered into STM if P1 is still in that state. Thus, the greater the degree of displacement or decay of P1 prior to the occurrence of P2, the greater the probability that P2 will be attended to and receive a full measure of processing effort with the ultimate result being a facilitation of LTM. Easily rehearsed materials can be maintained in STM for considerable periods of time, and therefore displacement of or interference with the P1 trace may be the critical factor. Of course, this is completely contradictory to the consolidation and rehearsal theories, which predict

that disruptions of the processing of P1 leads to poor LTM for repetitions. In addition, there is some evidence that the spacing effect for the long-term retention of complex visual pictures, stimuli which are not rehearsed (e.g., Shaffer & Shiffrin, 1972), is primarily a time-dependent function (Hintzman & Rogers, 1973).

Recent advances in the study of animal memory and habituation have provided some data which bear a striking resemblance to the phenomena of interest in this paper. In a series of three experiments, Whitlow, 1975) explored the short-term habituation of auditory-evoked peripheral vasoconstriction in rabbits. Pure tone stimuli were presented in pairs such that on any given trial the first and second members of the pair were either the same or different. The first experiment revealed that when the two stimuli were the same, there was a decrement in response to the second stimulus. The magnitude of the decrement was inversely related to the temporal spacing between the two stimuli (30, 60, or 150 sec) and was fully recovered by 150 sec. No decrement at any degree of spacing was found when the two stimuli of the pair were different. In the second and third experiments, intervening stimuli were found to disrupt the stimulus-specific response decrement, and the magnitude of the response to the repeated stimulus was a function of the number of intervening stimuli between the first and second presentations. These findings are quite similar to the variations in the cardiac and electrodermal responses found in the present experiment. They also suggest that both the temporal spacing and the number of intervening stimuli between P1 and P2 are important determinants of the response to P2.

Another relevant animal study by Davis (1970) found that the habituation of the acoustic startle response in the rat was composed of both short- and long-term components. Short-term response decrements were found to be inversely related to the interval between stimulus presentations, but the long-term decrement on a remote test was directly related to the length of the interval used during training. If one identifies the response decrements found in the Whitlow (1975) and Davis (1970) studies with decreased processing of repetitions as a result of memory for the stimulus, then animal and human memory processes would appear to share similar operating characteristics. This is precisely the conclusion reached by Wagner (1976) who has developed a comprehensive theory of habituation based upon recent models of human memory. While the theory will not be discussed in detail in this paper, it is worth noting that it shares many common features with two-process memory models (e.g., Atkinson & Shiffrin, 1968; Glanzer & Cunitz, 1966) in which the decay or displacement of information in STM plays a critical role.

The third experiment of this paper was designed as a first step in determining the extent to which differential processing of repetitions and the resulting effects on long-term retention are time dependent, at least for easily rehearsed verbal materials. A paradigm analogous to that used in the first experiment by Whitlow (1975) was employed.

EXPERIMENT 3

A modified version of the Whitlow (1975) paired-stimulus paradigm was used in the third experiment. The temporal interval between the first (P1) and second (P2) member of each stimulus pair was manipulated between presentation lists (10 sec vs. 20 sec). For any given trial there was an equal probability that P1 and P2 were either the same stimulus or two different stimuli.

The major objective behind the design of Experiment 3 was the assessment of temporal dependency in the differential processing of repetitions. The longer P1-P2 interval of 20 sec was chosen for several reasons. First, Hintzman (1974, 1976) has proposed that the spacing function asymptotes at about 15-20 sec, suggesting that the processes responsible for the differential processing of repetitions may have run their course by this time. Second, a number of classic studies on the temporal decay of information in STM (e.g., Murdock, 1961; Peterson & Peterson, 1959; Reitman, 1971, 1974) have indicated that substantial losses of information from STM can occur within 20 sec. Although the issue as to whether such losses are primarily due to decay, displacement, or interference has not been completely resolved, the evidence that a simple decay over time is at least partially responsible is quite strong. Third, it was judged that interpresentation intervals longer than 20 sec would have resulted in subjects becoming excessively drowsy during the list presentations, with

unpredictable effects on recall performance and psychophysiological responses. If the differential processing of repetitions is at all dependent on the time between P1 and P2, then greater recall for repeated words and larger P2-evoked cardiac decelerations and skin conductance responses should occur with the 20-sec P1-P2 interval.

An additional benefit of the experimental design was the allowance for a partial replication of Experiment 2, in which a massed presentation schedule with a 10-sec interval between repetitions was used. Since this part of the second experiment was comparable to the 10 sec interval condition in Experiment 3, similar findings with respect to the three dependent measures would strengthen the position that repetitions are deficiently processed when they are successive and separated by a relatively short period of time.

The stimulus specificity of differential psychophysiological responses was explored by comparing responses for P1 and P2 when the two stimuli were the same with those occurring for different stimulus pairs. The efficiency of this strategy was previously demonstrated by Whitlow (1975).

Method

Subjects

Five males and seven females were drawn from the same source and satisfied the same selection criteria required in the first two experiments. Subjects ranged in age from 18 to 29 with a mean of 20.4 years. Two additional subjects who became drowsy during the list presentations were replaced.

Stimulus Lists and Design

The experimental word lists (A - B) were the same as those used in the previous two experiments. Each word list was used to construct one list of 52 presentation events consisting of 26 1P words and 13 2P words. Eight-event primacy and recency buffers were composed of four 1P words and two 2P words. The buffers were not included in any data tabulations or analyses. Within each 36-event functional presentation list were 18 1P words occupying 18 positions and 9 2P words occupying the additional 18 positions.

Each two successive presentation events constituted a stimulus pair, making a total of 26 pairs per list. For half of the pairs, P1 and P2 were the same stimulus word. The other 13 pairs had different stimulus words for P1 and P2. Same and different stimulus pairs were randomly assigned to list positions within each 52-event presentation list: Two same and two different pairs were assigned to each primacy and recency buffer, and nine of each type of stimulus pair were assigned to the functional presentation lists.

In the presentation sequence constructed from Word List A, the average serial positions of 1P and 2P words (last occurrence) were 27.3 and 26.2, respectively. The respective positions for the Word List B presentation sequence were 27.1 and 26.4. Unlike the first two experiments, the probability of a repetition is most appropriately conceived on the basis of individual stimulus pairs rather than the total presentation list. Thus, given P1 of any stimulus pair, the probability that P2 would be either a repetition or a different stimulus word was .50.

Subjects were each presented and subsequently recalled one A list and one B list, in which the P1-P2 interval was either 10 sec or 20 sec. The ordering of interval conditions (10 sec - 20 sec) and the ordering of word lists (A - B) were both counterbalanced across the 12 subjects. Thus, the effects associated with the two counterbalanced orderings constituted two crossed, between-subjects factors. Interval condition was a within-subjects factor, while presentation type (P1 - P2) and same-different stimulus pair varied within both lists and subjects.

Apparatus, Procedures, and Data Analyses

The apparatus was identical to that used in Experiment 2; however, a number of procedural changes were necessary to accommodate the third experiment. First the timing of stimulus presentations was modified. The P1-P2 interval was either 10 sec or 20 sec depending on the interval condition. A constant 15-sec inter-pair interval was always in effect for both interval conditions. Second, the position of stimulus owrds on the scope display was arranged to cue the stimulus pairs: P1 presentations were displayed on the top portion of the scope face while P2 presentations were displayed on the bottom. Third, instructions to subjects were modified in accord with the procedural and design changes.

The basic instructions from Experiments 1 and 2 were altered to include the following: (a) subjects were told that they would be presented lists of word pairs with the first word of each pair always appearing at the top of the display and the second word always appearing at the bottom and that for any given pair there was a 50-50 chance that the first and second words would be either the same or different;

(b) the timing of stimulus presentations was carefully explained to all subjects immediately before the experimental session; (c) subjects were instructed to recall as many words from each list as possible, and that the order of recall or the recall of words in pairs was not at all important; (d) additional emphasis was placed on remaining alert and watching the scope display at all times.

The methods of data analysis were analogous to those employed in the second experiment.

Results

Recall

The probabilities of recall for 1P and 2P words as a function of interval condition are graphically presented in Figure 7. Note that 1P1 denotes those single words occurring in the P1 position of different stimulus pairs, and that 1P2 represents single words in the P2 position of different stimulus pairs. The major result evident in Figure 7 is that recall for 2P words was greater in the longer interval condition. Recall for 2P words in the 10-sec condition was no better than the recall for single words, reminiscent of the results from the second experiment. In contrast, when 20 sec separated repetitions, there was some increase in recall for repeated words over singly presented words. There was also a slight tendency toward greater recall for both 1P1 and 1P2 words with the longer 20-sec interval.

An analysis of recall scores (Appendix G, Table 10) revealed a significant interval condition x presentation type interaction,

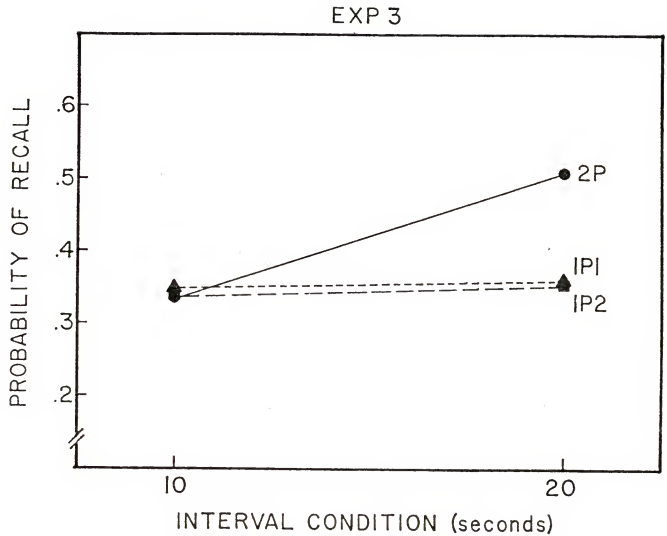


Figure 7. Experiment 3: Mean probability of recall for single presentation words (1P1 and 1P2) and repeated words (2P) as a function of interval condition.

$F(2,16)=4.01$, $p < .05$. A Duncan Test on this interaction disclosed a reliable difference in recall probability between 2P words in the 20-sec condition and all other combinations of the two factors ($p < .05$). No other pairwise comparisons were significant.

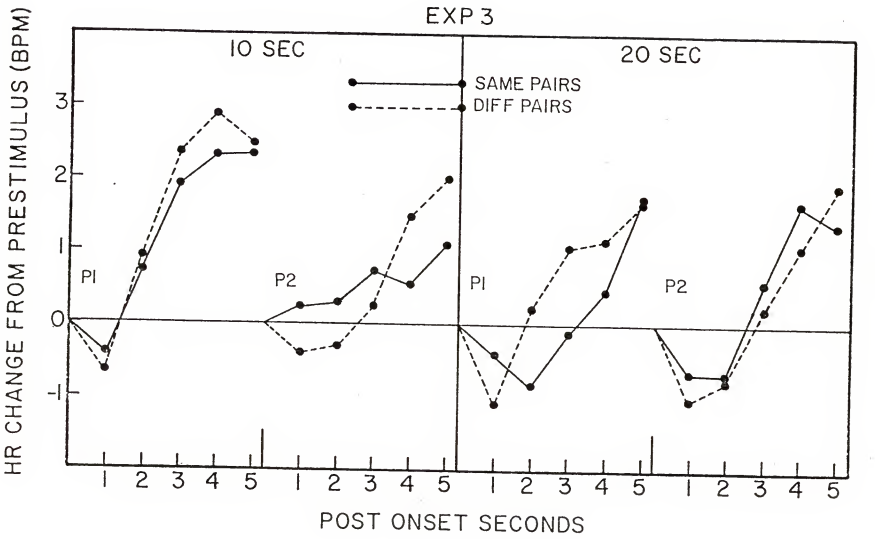
The analysis also revealed that one additional effect was significant, a condition order x list order x interval condition interaction $F(1,8)=7.86$, $p < .05$. This interaction is attributable to a combination of subject and order effects and cannot account for the disproportionate greater recall for 2P words in the 20-sec interval condition.

Heart Rate

The HR responses evoked by P1 and P2 presentations for both same and different stimulus pairs are illustrated in Figure 8. Responses also appear as a function of the interval condition. Each curve is the average of 108 individual curves, 9 per subject. As in the previous two experiments, the results of primary interest were examined via planned comparisons. Complete summary tables for the HR analyses are presented in Appendix H (Tables 11-13).

All HR responses were biphasic, except for the P2 response (same pair) in the 10-sec interval condition. The trend in HR change across the five poststimulus seconds was predominantly a linear acceleration [seconds $F(4,40)=26.42$, $p < .001$; linear seconds $F(1,10=36.86$, $p < .001$; cubic seconds $F(1,10)=5.96$, $p < .005$; see Table 11]. The initial attention-related response component (prestimulus second vs. first poststimulus second) showed some variation across the eight presentation type x interval condition combinations, $F(7,70)=2.29$, $p < .05$. Planned comparisons revealed only two reliable effects: a difference

Figure 8. Experiment 3: Mean heart rate change in beats per min for 5 sec following stimulus presentation plotted as differences from a 1 sec prestimulus baseline. Curves represent responses to the first (P1) and second (P2) presentations of a word pair where P1 and P2 were either the same or different words. Responses also appear as a function of interval condition (10 sec - 20 sec).


EXP 3
10 SEC
20 SEC
SAME PAIRS
DIFF PAIRS
HR CHANGE FROM PRESTIMULUS (BPM)
3
2
1
0
-1
P1
P2
P1
P2
1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5
POST ONSET SECONDS

in the P2 response as a function of the interval condition [$F(1,10)=7.49$, $p < .05$] and an overall interval condition effect, $F(1,10)=7.63$, $p < .05$. In general, larger decelerations occurred in the 20-sec condition, but the greatest difference between the two interval conditions was reflected in the P2 response.

The rehearsal-related trend in HR across the five poststimulus seconds also varied somewhat across the eight presentation type x interval condition combinations [seconds $F(28,280)=2.00$, $p < .01$], but these differences were manifested only in the quadratic [$F(7,70)=4.77$, $p < .01$] and cubic [$F(7,70)=2.60$, $p < .05$] seconds trends. Several comparisons involving these higher-order trends were statistically significant but not readily interpretable. For completeness, however, the following comparisons achieved significance: P1 x same-different pair x quadratic seconds [$F(1,10)=9.19$, $p < .05$]; P1 x interval condition x quadratic seconds [$F(1,10)=12.86$, $p < .01$]; P1 x P2 x interval condition x quadratic seconds [$F(1,10)=9.28$, $p < .05$].

Heart rate responses to the four presentation types were also analyzed separately within each interval condition (Tables 12 and 13). For the 10-sec condition, there were no reliable comparisons involving the initial deceleratory response component. However, there was a significant difference in the linear seconds trend between P1 and P2 (same pair), $F(1,10)=5.02$, $p < .05$, perhaps reflecting a difference in the amount of rehearsal for the two presentations. One additional comparison involving a quadratic seconds trend difference between P1 and P2 (different pair) was also significant $F(1,10)=15.94$, $p < .01$.

Comparisons among responses in the 20-sec condition also revealed no reliable differences in the deceleratory response component,

although two comparisons for the quadratic seconds trend across the five poststimulus seconds were significant: The P1 response differed between same and different stimulus pairs [$F(1,10)=9.26$, $p < .05$], and there was also a significant P1 x P2 x same-different pair interaction, $F(1,10)=8.17$, $p < .05$. Both of these comparisons involving the quadratic seconds trend reflect the tendency for the deceleratory response component to peak later for the same pair responses.

There was no indication that the HR responses changed across the three trial block (see Tables 12 and 13). In addition, an analysis of prestimulus HR levels, presented in Table 11, disclosed no differences between the eight presentation type x interval condition combinations or any other reliable main effects or interactions.

Despite the general lack of statistical reliability for HR response differences involving the initial deceleratory component, the pattern of results was for the most part consistent with the predicted outcome of the experiment. Two aspects of the data presented in Figure 8 are worth noting. First, P2 responses for repetitions varied as a function of the interval condition. In the 10-sec condition, there was a conspicuous absence of cardiac deceleration, but with the longer interval there was still a deceleratory response component for repetitions. Second, deceleratory responses evoked by P1 and P2 when the two stimuli were different were quite comparable in both interval conditions.

The absence of a deceleratory response to repetitions in the 10-sec condition is in accord with the results of Experiment 2. Since the differences in the HR response between P1 and the P2 repetition were not statistically reliable in either experiment, the HR responses

from the comparable conditions in the two experiments were pooled. The resulting HR response curves are presented in Figure 9. Each curve is the average of 216 individual curves, 9 for each of the 24 subjects. To determine if this increase in the number of observations yielded greater reliability for the differences between the P1 and P2 cardiac responses, paired-*t* tests on each second were performed. The only significant difference between the P1 and P2 responses occurred in the first poststimulus second [$t(23)=1.98$, $p < .05$, one-tailed), confirming that the lack of a deceleratory cardiac response to successive, closely spaced repetitions is a reliable effect. This finding was not attributable to differences in prestimulus HR levels, $t(23)=.01$, $p > .25$.

Skin Conductance

Average SCR amplitudes evoked by P1 and P2 presentations for both same and different stimulus pairs are graphically presented in Figure 10. Responses also appear as a function of the interval condition.

In the 10-sec condition there was considerable decrement in the P2 response when P1 and P2 were the same, similar to the findings of Experiment 2. However, in the case where P1 and P2 were different stimuli, there was little difference in the SCR amplitudes for the two presentations.

When 20-sec separated P1 and P2 presentations, there was still some decrement in the response to repetitions, but the magnitude of the effect was much smaller than with the shorter interval. Response amplitudes for the different P1 and P2 stimulus presentations were nearly equivalent. In addition, there was a tendency for all responses in the 20-sec condition to be larger than those in the 10-sec condition.

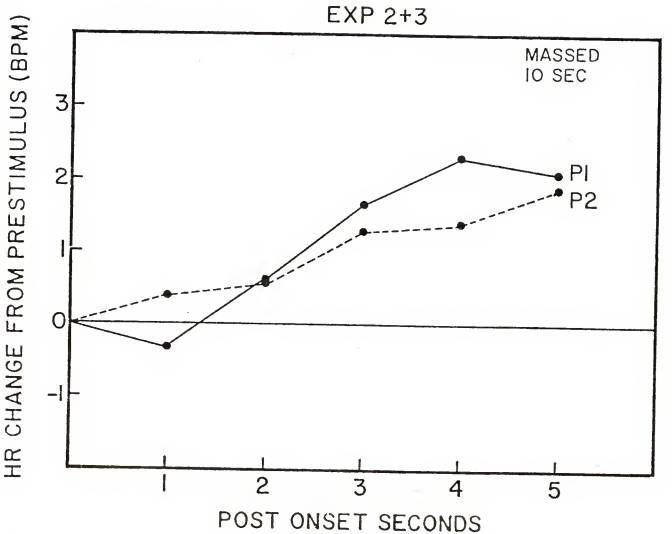


Figure 9. Experiments 2 and 3: Mean heart rate change in beats per min for 5 sec following stimulus presentation plotted as differences from a 1 sec prestimulus baseline. Curves represent responses to the first (P1) and second (P2) presentations of repeated words averaged across the MP condition from Experiment 2 and the 10 sec condition (same pairs) from Experiment 3.

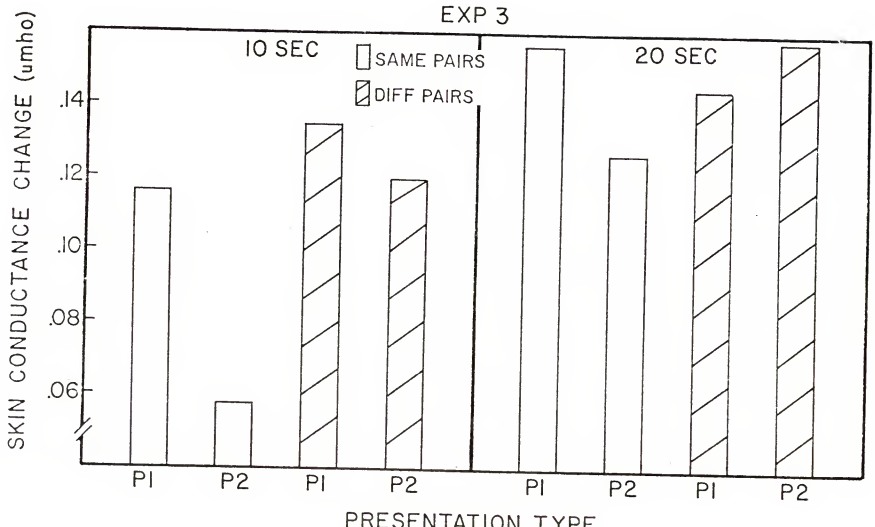


Figure 10. Experiment 3: Mean skin conductance change in micromhos following stimulus presentation. Bars represent responses to the first (P1) and second (P2) presentations of a word pair where P1 and P2 were either the same or different words. Responses also appear as a function of interval condition (10 sec - 20 sec).

The reliability of these effects was determined by an analysis of SCR scores (Appendix I, Table 14). The analysis disclosed a significant main effect of presentation type, $F(3,24)=5.03$, $p < .01$. A Duncan Test on this main effect revealed that the P2 response for repetitions was reliably smaller than the responses for the other three presentation types ($p < .05$). Although the interval condition x presentation type interaction failed to achieve statistical significance [$F(3,24)=.99$, $p > .10$), pairwise comparisons among the eight interval condition x presentation type means confirmed the a priori prediction that a decrement in the response to repetitions would occur only with the shorter interval: SCR amplitude for repetitions in the 10-sec interval condition was reliably smaller than the responses for all of the other seven combinations of the two factors ($p < .05$). No other comparisons were significant. The overall tendency for larger responses to occur with the longer interval was not significant [$F(1,8)=1.23$, $p > .10$], and there were no reliable effects involving the trial blocks factor.

Discussion

The results of Experiment 3 demonstrated that the LTM for repeated words is at least partially a function of the temporal spacing between repetitions. Cardiac and skin conductance responses evoked by repetitions were also differentially affected by the two temporal intervals. In addition, the stimulus specificity of differential psychophysiological responses was revealed in the comparisons between same and different stimulus pairs.

In the 10-sec interval condition, recall for repeated words was no better than for words presented only once. The cardiac response to P2 repetitions showed a conspicuous absence of a deceleratory component, and SCR amplitude for repetitions was greatly diminished in comparison to responses evoked by the other presentation types. This pattern of results is essentially identical to that found in the massed presentation condition in Experiment 2. Thus, deficient processing of successive, temporally close repetitions was revealed in both experiments. The consistent lack of cardiac deceleration indicates that attentional processes are involved. However, in the present experiment the linear HR acceleration evoked by P1 was reliably greater than the acceleration evoked by repetitions. If the two components of the cardiac response truly reflect attention-related and rehearsal-related processes, then this latter finding suggests that closely spaced repetitions are not rehearsed to the same extent as new items or repetitions which are more remote. Of course, the differential rehearsal of repetitions is entirely consistent with the position of this paper, and it seems intuitively reasonable that a stimulus demanding little attentional capacity would also be devoted less processing effort for rehearsal. An important aspect of the observed difference in HR acceleration between P1 and P2 was that the decreased acceleration did not result in a greater tendency toward deceleration. This provides additional support for considering the two components of the cardiac response as reflecting different stages in the processing of the stimulus words. While it is not entirely clear why differences in the rehearsal-related component of the HR response were not apparent in the first two experiments, one possibility may be that the more

structured paired-stimulus paradigm used in the present experiment permitted stubjects to develop a more definitive rehearsal strategy.

When 20 sec separated P1 and P2 presentations, the recall for repetitions showed a reliable improvement over the recall for once-presented items. The magnitude of the difference in recall between repeated words and single words was considerably less than that which would be expected if the two presentations of a repetition were processed as two independent stimuli. This is in contrast to the distribution effect in recall found in the first two experiments, where the separation of P1 and P2 by intervening items resulted in the recall for repetitions either meeting or exceeding the independence baseline.

Cardiac deceleration and SCRs evoked by repetitions in the 20-sec condition tended to be only slightly smaller than responses to the other presentation types, and the differences were not significant. This indicates that a substantial amount of processing capacity was allocated to repetitions, unlike the findings with the 10-sec interval. The improved recall for repetitions in the 20-sec condition reflected the additional processing devoted to P2. In addition, there was an overall tendency for both psychophysiological responses to be larger in the 20-sec condition. This effect was reliable only for the initial HR response component, but the skin conductance data exhibited the same pattern. The longer combination of interstimulus intervals resulted in a greater temporal isolation of stimulus presentations, and this may have been responsible for the overall interval effect. Similar findings with respect to interstimulus interval length and human autonomic responses have been reported elsewhere (see Graham, 1973). It is interesting that recall for both 2P and 1P words was greater in

the 20-sec condition, but in the case of 1P words the interval effect was quite small and not statistically significant.

Cardiac and skin conductance responses evoked by P1 and P2 for the different stimulus pairs were quite comparable and were not differentially affected by the interval condition. These findings are hardly surprising but nevertheless confirm the stimulus specificity of psychophysiological responses to repetitions. Within the limited range of P1-P2 intervals used in the present experiment, the results were clearly in accord with the finding of Whitlow (1975). The LTM for P1 and P2 (different pair) presentations was nearly identical, consistent with the equivocal allocations of processing capacity as indexed by the two psychophysiological measures.

The three experiments reported in this paper did not allow for the differentiation of displacement or interference effects and temporal effects. It should be remembered, however, that Experiment 3 was designed primarily to ascertain whether the temporal spacing between repetitions plays any role in determining the effectiveness of repeated stimulation. Given this rationale, it may be concluded that time is one important parameter affecting the differential processing of repetitions and that the LTM for repeated events is a function of such processing variations.

The proposal by Hintzman (1974, 1976) suggesting that the spacing effect for LTM asymptotes at 15 or 20 sec and is primarily a function of the time between repetitions is not consistent with the findings of the present research. In Experiment 3, recall for repeated words improved with the increase in temporal spacing from 10 to 20 sec. However, in the second experiment the difference in the recall for repeated

words between the MP (10-sec temporal spacing) and DP (four intervening items and a 50-sec temporal spacing) conditions was much greater. Either the effectiveness of temporal spacing continues beyond a 20-sec interval or intervening stimulus items are also effective determinants of the differential processing and LTM for repetitions, at least for easily-rehearsed verbal materials. Previous research with both humans (e.g., Madigan, 1969; Melton, 1967, 1970; Underwood, 1969, 1970) and animals (Whitlow, 1975) suggests that displacement or interference effects are important.

Clearly, much parametric research must be done before the relative contributions of these two determinants of the efficacy of repetition can be precisely described. Parallel investigations using both verbal stimuli and complex visual or auditory stimuli would be most informative. The strategy of combining psychophysiological indices of information processing and more traditional cognitive measures could be further exploited. In addition, the use of more central, fast-acting response measures such as the P300 component of the vertex evoked potential would allow the investigation of a much broader range of spacing intervals.

CONCLUSIONS AND IMPLICATIONS

This dissertation has reported the results of research based upon a relatively new approach in the study of human memory: the synthesis of methods and theory from the fields of psychophysiology and information processing. Cardiac and electrodermal responses proved to be reliable, unobtrusive indicators of attention and effort. By combining these psychophysiological measures with a traditional free-recall test of LTM, a number of important findings concerning the effects of repetition, distribution, and temporal spacing on memory were discovered. First, the locus of effects was identified with the differential processing of repetitions. Second, the amount of attentional capacity and processing effort devoted to the second presentation of a repeated stimulus was found to depend upon the number of intervening stimuli or the temporal spacing between presentations. Third, the variable processing requirements for repetitions also influenced the allocation of processing capacity to stimuli immediately following repetitions, with concordant effects on memory. In addition, the stimulus specificity of observed variations in psychophysiological responses to repeated stimuli was confirmed.

These findings appear to be most consistent with an attentional explanation of repetition effects. In particular, two-process theories of memory, centering around a limited-capacity STM, seem most applicable to the present data (e.g., Atkinson & Shiffrin, 1968; Glanzer, 1969,

1972; Glanzer & Cunitz, 1966). The amount of attention and processing effort devoted to a repeated stimulus would thus be determined by the degree to which it is already represented in STM upon the occasion of its second presentation. If it is well represented, it will be allocated little or no attentional capacity, and processing effort will be devoted to other information. However, if the first presentation is no longer well represented in STM, via either temporal decay or displacement by subsequent stimulation, then the repetition will be attended to and processed much like a new stimulus. One additional assumption, that the LTM for a stimulus is a function of the total amount of attentional capacity and processing effort allocated to that stimulus, completes the explanation.

Wagner (1976) has developed a comprehensive theory of habituation and animal memory which is of the same flavor as the two-process human memory models. Short- and long-term response decrements are viewed as reflecting the altered processing of repeated stimuli, and these alterations are attributed to a prior representaiton of the stimulus. The theory assumes that a limited-capacity STM is responsible for short-term response decrements, while the long-term decrements are ascribed to the cue-initiated retrieval of a consolidated long-term trace whose strength depends upon the amount of processing a stimulus receives while it is resident in STM. The findings of Whitlow (1975) and Davis (1970) are encompassed by the theory, and the psychophysiological response decrements found in the present experiments might be similarly interpreted.

Habituation has generally been considered an involuntary decrease in responsiveness to repetitive presentations of stimuli which are

devoid of signal characteristics. The stimuli used in the present experiments certainly do not fit this description, and there is no evidence to argue that the observed response decrements were either voluntary or involuntary in nature. However, Hintzman (1974) has proposed that the effects of the spacing of repetitions on memory may be caused by a habituation-recovery process. Attempts at eliminating or attenuating spacing and distribution effects by manipulations of voluntary attention have generally not been successful (D'Agostino & DeRemer, 1973; Elmes, et al., 1973; Hintzman et al., 1975), and these effects persist even in incidental learning situations (Shaughnessy, 1975). While there is little evidence that the spacing effect is related to voluntary processes, Hintzman, Summers, and Block (1975) were unable to firmly establish the validity of the habituation-recovery hypothesis. It should be noted that the rationale behind their experiments was that increasing the duration of P1 or preceeding P1 with a series of massed presentations of the same stimulus would produce varying degrees of habituation and affect the time course of recovery, which was the presumed process underlying the spacing effect. However, to this writer's knowledge, there are no data from the habituation literature to suggest that either of these manipulations would have the proposed effects on the time course of recovery from habituation. Thus, the question as to whether voluntary or involuntary processes are responsible for spacing and distribution effects and related psychophysiological response decrements awaits future research. The exciting possibility is that the continuity of findings from the diverse research areas of habituation, animal memory, and human information processing suggest that at some level a common memory mechanism is involved.

The present research also has important implications for the study of human memory development. Wilson (1976) found a developmental trend in the lag effect for free recall with children of different school grades. Children from the fourth grade showed only a distribution effect in that recall for repeated stimuli improved between a lag of 0 and a lag of 2 with no further improvements up to a lag of 8. In contrast, eighth grade school children showed a continuous increase in recall as lag increased, and the lag function for these subjects roughly paralleled that for a control group of college age subjects. Wilson (1976) interpreted his results as indicating that the younger children possess a small capacity STM, an explanation consistent with the position of this paper. It would be most informative to determine if concordant changes in psychophysiological response measures accompany such developmental trends in memory processes.

More critical for the study of memory development is the fact that psychophysiological measures have become a primary tool for investigating attentional processes and habituation at the pre-verbal levels. Phasic decelerative cardiac resonses, indicative of orienting and attention, generally appear at about 6 weeks and increase up to 4 to 6 months of age (Graham & Jackson, 1970). Habituation also occurs quite readily at these ages. In addition, Adkinson and Berg (1976) and Clifton and Nelson (1976) have indicated that cardiac orienting and habituation occur even in the newborn under appropriate conditions. Thus, it appears that at least a rudimentary information storage and retrieval system is operational even at birth. While such findings are quite provocative, very little research directly relevant to memory processes in the infancy period has been carried out. A major reason for this is that

most memory research with adults and older children has depended heavily on paradigms which make use of the verbal and linguistic capabilities of the subjects and are thus of very little use in studying memory in infants. Paradigms employing psychophysiological responses were basically developed to study attention, discrimination, and habituation and are not very well suited to the systematic investigation of memory. The previous lack of continuity between theories of habituation and information-processing accounts of human memory has also impeded the progress of studies on infant memory.

The present research has established the value of psychophysiological measures for investigating memory processes, and the paradigms used could be easily adapted to study the effects of repetition and distribution on memory in infants. A psychophysiology of memory will ultimately permit the "tracking" of memory development from birth up through stages dominated by advanced cognitive processes.

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APPENDIX A

Experimental Word Lists

Word List A

1. Angle
2. Beard
3. Bench
4. Block
5. Brain
6. Brick
7. Cabin
8. Candy
9. Chain
10. Clerk
11. Cliff
12. Cloth
13. Cloud
14. Crowd
15. Crown
16. Drill
17. Ferry
18. Fluid
19. Frame
20. Ghost
21. Graph
22. Honey
23. Index
24. Lemon
25. Liver
26. Lodge
27. Motor
28. Novel
29. Porch
30. Rifle
31. Scope
32. Sleep
33. Spark
34. Stick
35. Storm
36. Straw
37. Title
38. Toast
39. Tower
40. Tract
41. Vapor
42. Wagon
43. Widow

Mean Frequency=34.5

Word List B

1. Actor
2. Arrow
3. Attic
4. Baker
5. Beach
6. Belly
7. Brace
8. Chair
9. Coach
10. Creek
11. Crime
12. Dairy
13. Depot
14. Drama
15. Dream
16. Fiber
17. Flame
18. Flesh
19. Glass
20. Globe
21. Grain
22. Lunch
23. Medal
24. Motel
25. Nurse
26. Paint
27. Panel
28. Pilot
29. Pupil
30. Ranch
31. Shaft
32. Sheet
33. Shirt
34. Snake
35. Steam
36. Sugar
37. Sweat
38. Tooth
39. Trail
40. Train
41. Truck
42. Uncle
43. Virus

Mean Frequency=34.9

APPENDIX B

Summary Table of the Analyses of Variance in the Probability of Recall for Experiment 1 (Table 1)

Table 1

Analyses of the Variance in the Probability of Recall for Experiment 1

		2P		1P'	
Source	df	MS	F	MS	F
Between Subjects (Ss)	11				
List Number (LN)	1	329.2	.32	1081.4	.76
Ss w/in Groups (Grps)	10	1028.2		1417.9	
Within Ss	84				
List Type (LT)	1	514.4	1.09	155.6	.24
LN x LT	1	251.9	.53	32.2	.05
LT x Ss w/in Grps	10	472.8		637.1	
Lag[a]	3	6887.7	8.61***	1770.8	2.71
LN x Lag	3	298.3	.37	1204.4	1.84
Lag x Ss w/in Grps	30	799.8		654.6	
LT x Lag	3	401.2	1.08	1122.7	1.50
LN x LT x Lag	3	138.9	.37	320.2	.43
LT x Lag x Ss w/in Grps	30	371.9		746.1	

Table 1 - continued

Source	df	2P MS	2P F	1P' MS	1P' F
Total	95	783.5		811.5	

[a] The factor Lag includes the probability of recall of 1P items as a level.

* $p < .05$

** $p < .01$

*** $p < .001$

APPRENDIX C

Summary Tables of the Analyses of Variance
in Heart Rate Change for Experiment 1
(Tables 2-4)

Table 2

Analyses of the Variance in Heart Change for Experiment 1:
P1-P2 and P1-1P' as a Function of Lag

Source	df	P1-P2 MS	P1-P2 F	P1-1P' MS	P1-1P' F
Between Subjects (S)	11				
List Number (LN)	1	584.2	.17	425.4	.12
Ss w/in Groups (Grps)	10	3469.0		3408.6	
Within Ss	852				
[Presentation Type (PT) x Lag]	5	55.3	2.71*	63.0	3.32*
LN x (PT x Lag)	5	33.0	1.61	24.4	1.29
LN x (PT x Lag) x Ss w/in Grps	50	20.4		19.0	
Trial Blocks (TB)	1	1281.7	3.98	1661.0	4.90
LN x TB	1	357.9	1.11	593.5	1.75
LN x TB x Ss w/in Grps	10	321.7		339.3	
Seconds (Sec)	5	160.6	17.79***	229.3	21.15***
Linear	1	682.6	84.08***	1038.8	76.90***
Quadratic	1	56.2	2.91	14.9	.62
Cubic	1	56.9	12.11**	87.9	11.77**

Table 2 - continued

Source	df	P1-P2 MS	P1-P2 F	P1-1P' MS	P1-1P' F
LN x Sec	5	5.71	.63	.9	.08
Linear	1	16.0	1.97	.1	.00
Quadratic	1	8.6	.44	1.0	.04
Cubic	1	2.0	.43	2.2	.29
LN x Sec x Ss w/in Grps	50	9.0		10.9	
Linear	10	8.1		13.5	
Quadratic	10	19.4		24.0	
Cubic	10	4.7		7.5	
(PT x Lag) x TB	5	24.1	.66	28.2	.83
LN x (PT x Lag) x TB	5	24.4	.67	41.1	1.22
LN x (PT x Lag) x TB x Ss w/in Grps	50	36.5		33.8	
(PT x Lag) x Sec	25	7.4	1.39	7.6	1.17
Linear	5	12.4	.94	12.3	.77
Quadratic	5	11.2	2.13	13.6	1.51
Cubic	5	20.5	1.02	8.8	2.32

Table 2 - continued

Source	df	P1-P2		P1-1P'	
		MS	F	MS	F
LN x (PT x Lag) x Sec	25	7.4	1.40	6.4	.98
Linear	5	25.1	1.91	16.0	1.01
Quadratic	5	4.9	.93	9.5	1.05
Cubic	5	2.8	.68	2.2	.58
LN x (PT x Lag) x Sec x Ss w/in Grps	250	5.3		6.5	
Linear	50	13.1		15.9	
Quadratic	50	5.2		9.0	
Cubic	50	4.0		3.8	
TB x Sec	5	6.1	.64	2.6	.54
Linear	1	14.6	.39	1.9	.13
Quadratic	1	.1	.04	5.8	1.24
Cubic	1	6.1	1.85	2.7	1.24
LN x TB x Sec	5	6.1	.64	.7	.15
Linear	1	11.5	.31	.7	.05
Quadratic	1	4.1	1.32	1.9	.40

Table 2 - continued

Source	df	P1-P2 MS	P1-P2 F	P1-1P' MS	P1-1P' F
Cubic	1	3.4	1.02	.8	.35
LN x TB x Sec x Ss w/in Grps	50	9.6		4.8	
Linear	10	37.0		14.7	
Quadratic	10	3.1		4.6	
Cubic	10	3.3		2.2	
(PT x Lag) x TB x Sec	25	3.3	.68	6.0	1.01
Linear	5	2.2	.21	9.1	.66
Quadratic	5	5.9	.89	7.8	.96
Cubic	5	3.6	1.07	8.1	2.24
LN x (PT x Lag) x TB x Sec	25	2.5	.51	3.1	.52
Linear	5	5.2	.49	5.5	.40
Quadratic	5	2.8	.41	3.5	.44
Cubic	5	.8	.23	2.7	.76
LN x (PT x Lag) x TB x Sec x Ss w/in Grps	250	4.9		5.9	
Linear	50	10.6		13.8	

Table 2 - continued

Source	df	P1-P2 MS	P1-P2 F	P1-1P' MS	P1-1P' F
Quadratic	50	6.7		8.1	
Cubic	50	3.4		3.6	
Total	863	56.2		57.0	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 3

Analysis of the Variance in Heart Rate Change for Experiment 1 lP' as a Function of Lag

Source	df	MS	F
Between Subjects (Ss)	11		
List Number (LN)	1	76.2	.05
LN x Ss w/in Groups (Grps)	10	1638.9	
Within Ss	420		
Lag	2	107.9	5.24*
LN x Lag	2	5.9	.29
LN x Lag x Ss w/in Grps	20	20.6	
Trial Blocks (TB)	1	788.5	4.58
LN x TB	1	487.8	2.83
LN x TB x Ss w/in Grps	10	172.2	
Seconds (Sec)	5	117.3	11.61***
Linear	1	493.3	45.74***
Quadratic	1	12.7	.51
Cubic	1	76.8	9.86*
LN x Sec	5	4.1	.41
Linear	1	.3	.03
Quadratic	1	13.2	.54
Cubic	1	6.0	.77
LN x Sec s Ss w/in Grps	50	10.1	
Linear	10	10.8	
Quadratic	10	24.7	
Cubic	10	7.8	

Table 3 - continued

Source	df	MS	F
Lag x TB	2	58.4	1.69
LN x Lag x TB	2	59.8	1.74
LN x Lag x TB x Ss w/in Grps	20	34.5	
Lag x Sec	10	12.7	1.39
Linear	2	21.8	.90
Quadratic	2	24.9	2.09
Cubic	2	12.7	2.90
LN x Lag x Sec	10	8.0	.88
Linear	2	24.3	1.00
Quadratic	2	6.4	.54
Cubic	2	1.3	.29
LN x Lag x Sec x Ss w/in Grps	100	9.1	
Linear	20	24.3	
Quadratic	20	11.9	
Cubic	20	4.4	
TB x Sec	5	3.6	.52
Linear	1	0.0	.00
Quadratic	1	6.0	.84
Cubic	1	5.1	2.28
LN x TB x Sec	5	.6	.08
Linear	1	.4	.02
Quadratic	1	1.0	.14
Cubic	1	1.0	.44
LN x TB x Sec x Ss w/in Grps	50	7.0	
Linear	10	21.2	

Table 3 - continued

Source	df	MS	F
Quadratic	10	7.1	
Cubic	10	2.2	
Lag x TB x Sec	10	11.4	1.37
Linear	2	17.8	1.04
Quadratic	2	13.3	1.01
Cubic	2	18.6	3.81*
LN x Lag x TB x Sec	10	4.5	.55
Linear	2	9.4	.55
Quadratic	2	.8	.06
Cubic	2	6.6	1.36
LN x Lag x TB x Sec x Ss w/in Grps	100	8.3	
Linear	20	17.1	
Quadratic	20	13.3	
Cubic	20	4.9	
Total	431	57.1	

*$p < .05$
**$p < .01$
***$p < .001$

Table 4

Analyses of the Variance in Heart Rate Change for Experiment 1: Comparisons of Trial Blocks for P1, P2, and 1P'

		P1		P2		1P'	
Source	df	MS	F	MS	F	MS	F
Between Subjects (Ss)	11						
List Number (LN)	1	139.3	.23	61.9	.11	25.4	.05
Ss w/in Groups (Grps)	10	598.0		567.6		546.3	
Within Ss	132						
Trial Blocks (TB)	1	291.2	4.55	149.7	2.76	262.8	4.58
LN x TB	1	51.0	.80	70.1	1.29	162.6	2.83
LN x TB x Ss w/in Grps	10	64.0		54.2		57.4	
Seconds (Sec)	5	38.2	20.98***	21.8	6.69***	39.1	11.61***
Linear	1	182.1	48.29***	65.4	19.74***	164.4	45.74**
Quadratic	1	1.2	.49	25.0	4.66	4.2	.51
Cubic	1	6.7	4.65	13.0	4.39	25.6	9.86*
LN x Sec	5	.4	.22	3.9	1.21	1.4	.41
Linear	1	0.0	.01	13.4	4.04	.1	.03
Quadratic	1	1.6	.68	1.3	.25	4.4	.54

Table 4 - continued

Source	df	P1 MS	P1 F	P2 MS	P2 F	1P' MS	1P' F
Cubic	1	.1	.03	2.0	.67	2.0	.77
LN x Sec x Ss w/in Grps	50	1.8		3.3		3.4	
Linear	10	3.8		3.3		3.6	
Quadratic	10	2.4		5.4		8.2	
Cubic	10	1.5		3.0		2.6	
TB x Sec	5	.6	.47	2.2	.62	1.2	.52
Linear	1	1.5	.32	2.7	.24	0.0	.00
Quadratic	1	.3	.58	.1	.03	2.0	.84
Cubic	1	0.0	.00	3.8	2.17	1.7	2.28
LN x TB x Sec	5	.7	.55	2.4	.65	.2	.08
Linear	1	.1	.02	4.9	.42	.1	.02
Quadratic	1	2.9	5.56 *	1.0	.36	.3	.14
Cubic	1	0.0	.04	1.8	1.01	.3	.44
LN x TB x Sec x Ss w/in Grps	50	1.2		3.6		2.3	
Linear	10	4.5		11.6		7.1	

Table 4 - continued

Source	df	P1 MS	P1 F	P2 MS	P2 F	1P' MS	1P' F
Quadratic	10	.5		2.8		2.4	
Cubic	10	.6		1.7		.7	
Total	143	52.1		48.9		48.8	

* $p < .05$
** $p < .01$
*** $p < .001$

APPENDIX D

Summary Table of the Analysis of Variance
in the Probability of Recall for Experiment 2
(Table 5)

Table 5

Analysis of the Variance in the Probability of Recall for Experiment 2

Source	df	MS	F
Between Subjects (Ss)	11		
Condition Order (CO)	1	83.9	.08
List Order (LO)	1	139.0	.14
CO x LO	1	495.6	.48
Ss w/in Groups (Grps)	8	1022.2	
Within Ss	60		
Distribution Condition (DCON)	1	42.7	.08
CO x DCON	1	138.8	.26
LO x DCON	1	1443.3	2.75
CO x LO x DCON	1	496.4	.94
DCON x Ss w/in Grps	8	525.4	
Presentation Type (PT)	2	714.8	3.69*
CO x PT	2	73.7	.38
LO x PT	2	128.6	.66
CO x LO x PT	2	290.3	2.82
PT x Ss w/in Grps	16	193.9	
DCON x PT	2	1328.8	12.90***
CO x DCON x PT	2	36.0	.35
LO x DCON x PT	2	290.3	2.82
CO x LO x DCON x PT	2	691.5	6.71**
DCON x TP x Ss w/in Grps	16	102.9	

Table 5 - continued

Source	df	MS	F
Total	71	379.1	

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* $p < .05$
** $p < .01$
*** $p < .001$

APPENDIX E

Summary Tables of the Analyses of Variance
in Heart Rate Change for Experiment 2
(Tables 6-8)

Table 6

Analyses of the Variance in Heart Rate Change for Experiment 2: Prestimulus Sec, Prestimulus Sec - First Poststimulus Sec, and All Poststimulus Sec as a Function of Presentation Type and Distribution Condition

	Pre Sec			Pre Sec - First Post Sec			All Post Sec		
Source	df	MS	F	df	MS	F	df	MS	F
Between Subjects (Ss)	11			11			11		
Condition (CO)	1	1379.7	2.70	1	2916.0	2.89	1	6788.0	2.88
Ss w/in Groups (Grps)	10	511.5		10	1009.2		10	2355.8	
Within Ss	84			180			468		
[Presentation Type (PT) x Distribution Condition (DCON)]	7	2.0	.37	7	2.5		7	10.2	.48
CO x (PT x DCON)	7	32.2	5.88**	7	54.6	4.96**	7	109.0	5.18**
CO x (PT x DCON) x Ss w/in Grps	70	5.5		70	11.0		70	21.1	
Seconds (Sec)				1	3.0	2.98	4	42.5	16.60***
Linear							1	324.6	29.24***
Quadratic							1	39.1	4.85
Cubic							1	3.4	1.36
CO x Sec				1	2.2	1.45	4	4.4	.79

Table 6 - continued

Source	Pre Sec			Pre Sec - First Post Sec			All Post Sec		
	df	MS	F	df	MS	F	df	MS	F
Linear							4	14.6	1.32
Quadratic							1	.7	.08
Cubic							1	1.4	.55
CO x Sec x Ss w/in Grps				10	1.5		40	5.6	
Linear							10	11.1	
Quadratic							10	8.1	
Cubic							10	2.5	
(PT x DCON) x Sec				7	1.4	2.18*	28	1.0	.64
Linear							7	2.0	.50
Quadratic							7	.6	.61
Cubic							7	.8	1.30
CO x (PT x DCON) x Sec				7	1.5	2.36*	28	1.1	.71
Linear							7	2.5	.62
Quadratic							7	.9	.83
Cubic							7	.6	.93

Table 6 - continued

Source	Pre Sec df	Pre Sec MS	Pre Sec F	Pre Sec - First Post Sec df	Pre Sec - First Post Sec MS	Pre Sec - First Post Sec F	All Post Sec df	All Post Sec MS	All Post Sec F
CO x (PT x DCON) x Sec x Ss w/in Grps				70	.64		280	1.5	
Linear							70	4.0	
Quadratic							70	1.0	
Cubic							70	.6	
Total	95	74.9		191	74.7		479	70.4	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 7

Analyses of the Variance in Heart Rate Change for Experiment 2: Prestimulus Sec - First Poststimulus Sec, and All Poststimulus Sec as a Function of Presentation Type and Trial Blocks for MP Distribution Condition

	Pre Sec - First Post Sec			All Post Sec		
Source	df	MS	F	df	MS	F
Between Subjects (Ss)	11			11		
Condition Order (CO)	1	7905.8	5.38*	1	17537.6	4.78
Ss w/in Groups (Grps)	10	1469.2		10	3668.9	
Within Ss	276			708		
Presentation Type (PT)	3	8.3	.86	3	24.1	1.74
CO x PT	3	22.3	2.32	3	41.0	2.96*
CO x PT x Ss w/in Grps	30	9.6		30	13.8	
Trial Blocks (TB)	2	22.9	1.23	2	29.9	.73
CO x TB	2	9.3	.50	2	37.6	.92
CO x TB x Ss w/in Grps	20	18.6		20	41.0	
Seconds (Sec)	1	3.6	1.08	4	124.9	8.12***
Linear				1	455.6	10.88**
Quadratic				1	36.7	2.33
Cubic				1	5.7	1.87
CO x Sec	1	.6	.17	4	18.9	1.23
Linear				1	71.5	1.71
Quadratic				1	1.8	.11
Cubic				1	1.8	.60
CO x Sec x Ss w/in Grps	10	3.3		40	15.4	
Linear				10	41.9	
Quadratic				10	15.8	

Table 7 - continued

Source	Pre Sec - First Post Sec df	MS	F	All Post Sec df	MS	F
Cubic				10	3.1	
PT x TB	6	6.2	.80	6	14.6	.86
CO x PT x TB	6	13.7	1.77	6	15.9	.94
CO x PT x TB x Ss w/in Grps	60	7.7		60	16.9	
PT x Sec	3	5.4	2.98*	12	2.3	.69
Linear				3	6.2	.77
Quadratic				3	1.9	.63
Cubic				3	.2	.10
CO x PT x Sec	3	9.3	5.14**	12	2.5	.75
Linear				3	5.4	.67
Quadratic				3	1.7	.54
Cubic				3	2.7	1.43
CO x PT x Sec x Ss w/in Grps	30	1.8		120	3.3	
Linear				30	8.0	
Quadratic				30	3.1	
Cubic				30	1.9	
TB x Sec	2	.4	.20	8	4.3	1.50
Linear				2	14.3	2.05
Quadratic				2	1.2	.41
Cubic				2	1.0	.86
CO x TB x Sec	2	1.2	.63	8	6.5	2.26
Linear				2	23.2	3.33
Quadratic				2	.8	.26

Table 7 - continued

Source	Pre Sec - First Post Sec df	MS	F	All Post Sec df	MS	F
Cubic				2	1.7	1.54
CO x TB x Sec x Ss w/in Grps	20	1.9		80	2.9	
Linear				20	7.0	
Quadratic				20	3.0	
Cubic				20	1.1	
PT x TB x Sec	6	1.5	.71	24	5.5	1.62
Linear				6	13.9	1.89
Quadratic				6	4.1	1.25
Cubic				6	3.5	1.43
CO x PT x TB x Sec	6	1.6	.77	24	2.9	.84
Linear				6	2.6	.36
Quadratic				6	6.1	1.87
Cubic				6	2.1	.86
CO x PT x TB x Sec x Ss w/in Grps	60	2.1		240	3.4	
Linear				60	7.4	
Quadratic				60	3.3	
Cubic				60	2.4	
Total	287	84.8		719	83.4	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 8

Analyses of the Variance in Heart Rate Change for Experiment 2: Prestimulus Sec - First Poststimulus Sec, and All Poststimulus Sec as a Function of Presentation Type and Trial Blocks for DP Distribution Condition

	Pre Sec - First Post Sec			All Post Sec		
	df	MS	F	df	MS	F
Between Subjects (Ss)	11			11		
Condition Order (CO)	1	1879.9	1.10	1	4813.8	1.30
Ss w/in Groups (Grps)	10	1706.6		10	3700.0	
Within Ss	276			708		
Presentation Type (PT)	3	8.4	.47	3	35.1	1.06
CO x PT	3	14.0	.78	3	59.4	1.80
CO x PT x Ss w/in Grps	30	18.0		30	33.1	
Trial Blocks (TB)	2	84.6	1.28	2	147.9	1.26
CO x TB	2	103.6	1.56	2	161.4	1.37
CO x TB x Ss w/in Grps	20	66.2		20	117.8	
Seconds (Sec)	1	5.5	1.89	4	154.5	12.33***
Linear				1	519.1	17.23***
Quadratic				1	85.9	6.83*
Cubic				1	4.4	.79
CO x Sec	1	8.2	2.82	4	4.5	.36
Linear				1	.8	.03
Quadratic				1	11.2	.89
Cubic				1	2.3	.41
CO x Sec x Ss wi/in Grps	10	2.9		40	12.5	
Linear				10	30.1	
Quadratic				10	12.6	

Table 8 - continued

Source	Pre Sec - First Post Sec df	MS	F	All Post Sec df	MS	F
Cubic				10	5.6	
PT x TB	6	13.3	.63	6	23.3	.96
CO x PT x TB	6	5.3	.25	6	14.9	.61
CO x PT x TB x Ss w/in Grps	60	21.0		60	24.3	
PT x Sec	3	4.4	2.04	12	3.7	1.14
Linear				3	7.6	1.06
Quadratic				3	.8	.29
Cubic				3	5.3	2.75
CO x PT x Sec	3	.6	.27	12	1.4	.42
Linear				3	2.6	.37
Quadratic				3	.8	.26
Cubic				3	1.2	.64
CO x PT x Sec x Ss w/in Grps	30	2.1		120	3.3	
Linear				30	7.2	
Quadratic				30	2.9	
Cubic				30	1.9	
TB x Sec	2	3.3	1.53	8	4.8	1.10
Linear				2	2.7	.28
Quadratic				2	11.6	3.04
Cubic				2	4.7	1.39
CO x TB x Sec	2	1.8	.84	8	6.4	1.46
Linear				2	13.6	1.38
Quadratic				2	.3	.08

Table 8 - continued

Source	Pre Sec - First Post Sec df	MS	F	All Post Sec df	MS	F
Cubic				2	11.5	3.44
CO x TB x Sec x Ss w/in Grps	20	2.2		80	4.4	
Linear				20	9.8	
Quadratic				20	3.8	
Cubic				20	3.4	
PT x TB x Sec	6	3.0	1.51	24	3.3	.61
Linear				6	6.6	.48
Quadratic				6	2.3	.87
Cubic				6	3.4	.75
CO x PT x TB x Sec	6	2.4	1.22	24	2.3	.42
Linear				6	2.9	.21
Quadratic				6	2.0	.76
Cubic				6	3.1	.69
CO x PT x TB x Sec x Ss w/in Grps	60	2.0		240	5.3	
Linear				60	13.6	
Quadratic				60	2.6	
Cubic				60	4.5	
Total	287	80.0		719	71.2	

* $p < .05$
** $p < .01$
*** $p < .001$

APPENDIX F

Summary Table of the Analysis of Variance
in Skin Conductance Change for Experiment 2
(Table 9)

Table 9

Analysis of the Variance in Skin Conductance Change for Experiment 2

Source	df	MS	F
Between Subjects (Ss)	11		
Condition Order (CO)	1	.01546	.04
List Order (LO)	1	.61697	1.57
CO x LO	1	.45840	1.16
Ss w/in Groups (Grps)	8	.39415	
Within Ss	276		
Distribution Condition (DCON)	1	.01789	.28
CO x DCON	1	.48757	7.75*
LO x DCON	1	.05527	.88
CO x LO x DCON	1	.01430	.23
DCON x Ss w/in Grps	8	.06292	
Presentation Type (PT)	3	.00409	2.53
CO x PT	3	.00153	.95
LO x PT	3	.00691	4.28*
CO x LO x PT	3	.00303	1.88
PT x Ss w/in Grps	24	.00162	
Trial Blocks (TB)	2	.05225	3.39
CO x TB	2	.00832	.54
LO x TB	2	.02472	1.60
CO x LO x TB	2	.00227	.15
TB x Ss w/in Grps	16	.01541	
DCON x PT	3	.05006	5.86**

Table 9 - continued

Source	df	MS	F
CO x DCON x PT	3	.00826	.97
LO x DCON x PT	3	.01355	1.58
CO x LO x DCON x PT	3	.02241	2.62
DCON x PT x Ss w/in Grps	24	.00855	
DCON x TB	2	.00317	.25
CO x DCON x TB	2	.01762	1.41
LO x DCON x TB	2	.00719	.57
CO x LO x DCON x TB	2	.02589	2.07
DCON x TB x Ss w/in Grps	16	.01253	
PT x TB	6	.00520	.77
CO x PT x TB	6	.01346	2.00
LO x PT x TB	6	.00501	.74
CO x LO x PT x TB	6	.00784	1.16
PT x TB x Ss w/in Grps	48	.00673	
DCON x PT x TB	6	.00457	.80
CO x DCON x PT x TB	6	.00561	.98
LO x DCON x PT x TB	6	.00341	.60
CO x LO x DCON x PT x TB	6	.00273	.48
DCON x PT x TB x Ss w/in Grps	48	.00572	
Total	287	.02617	

* $p < .05$
** $p < .01$
*** $p < .001$

APPENDIX G

Summary Table of the Analysis of Variance
in the Probability of Recall for Experiment 3
(Table 10)

Table 10

Analysis of the Variance in the Probability of Recall for Experiment 3

Source	df	MS	F
Between Subjects (Ss)	11		
Condition Order (CO)	1	1258.3	.79
List Order (LO)	1	316.7	.20
CO x LO	1	1691.7	1.06
Ss w/in Grps	8	1590.3	
Within Ss	60		
Interval Condition (ICON)	1	754.0	4.14
CO x ICON	1	604.0	3.32
LO x ICON	1	95.7	.53
CO x LO x ICON	1	1431.1	7.86*
ICON x Ss w/in Grps	8	182.1	
Presentation Type (PT)	2	428.6	1.73
CO x PT	2	294.8	1.19
LO x PT	2	305.3	1.23
CO x LO x PT	2	349.8	1.41
PT x Ss w/in Grps	16	247.4	
ICON x PT	2	529.3	4.01*
CO x ICON x PT	2	66.5	.50
LO x ICON x PT	2	213.6	1.62
CO x LO x ICON x PT	2	175.3	1.33
ICON x PT x Ss w/in Grps	16	132.1	

Table 10 - continued

Source	df	MS	F
Total	71	438.4	

* $p < .05$
** $p < .01$
*** $p < .001$

APPENDIX H

Summary Tables of the Analyses of Variance
in Heart Rate Change for Experiment 3
(Tables 11-13)

Table 11

Analyses of the Variance in Heart Rate Change for Experiment 3: Prestimulus Sec, Prestimulus Sec - First Poststimulus Sec, and All Poststimulus Sec as a Function of Presentation Type and Interval Condition

	Pre Sec			Pre Sec - First Post Sec			All Post Sec		
Source	df	MS	F	df	MS	F	df	MS	F
Between Subjects (Ss)	11			11			11		
Condition Order (CO)	1	1734.6	2.14	1	3430.9	2.07	1	8663.5	2.11
Ss w/in Groups (Grps)	10	810.7		10	1658.0		10	4097.4	
Within Ss	84			180			468		
[Presentation Type (PT) x Interval Condition (ICON)]	7	5.8	1.11	7	12.4	1.25	7	15.5	.79
CO x (PT x ICON)	7	9.5	1.82	7	19.0	1.91	7	57.9	2.96**
CO x (PT x ICON) x Ss w/in Grps	70	5.2		70	9.9		70	19.6	
Seconds (Sec)				1	12.9	8.40*	4	93.6	26.24***
Linear							1	365.9	36.86***
Quadratic							1	2.1	.70
Cubic							1	4.6	5.96*
CO x Sec				1	.1	.08	4	2.0	.57

Table 11 - continued

Source	Pre Sec df	Pre Sec MS	Pre Sec F	Pre Sec - First Post Sec df	Pre Sec - First Post Sec MS	Pre Sec - First Post Sec F	All Post Sec df	All Post Sec MS	All Post Sec F
Linear							1	.1	.01
Quadratic							1	5.1	1.68
Cubic							1	2.2	2.87
CO x Sec x Ss w/in Grps				10	1.5		40	3.6	
Linear							10	9.9	
Quadratic							10	3.0	
Cubic							10	.8	
(PT x ICON) x Sec				7	1.0	2.29*	28	3.0	2.00**
Linear							7	4.1	1.08
Quadratic							7	6.1	4.77**
Cubic							7	1.4	2.60*
CO x (PT x ICON) x Sec				7	.8	1.76	28	2.9	1.99
Linear							7	9.3	2.48*
Quadratic							7	1.4	1.12
Cubic							7	.7	1.42

Table 11 - continued

Source	Pre Sec df	Pre Sec MS	Pre Sec F	Pre Sec - First Post Sec df	Pre Sec - First Post Sec MS	Pre Sec - First Post Sec F	All Post Sec df	All Post Sec MS	All Post Sec F
CO (PT x ICON) x Sec x Ss w/in Grps				70	.4		280	1.5	
Linear							70	3.8	
Quadratic							70	1.3	
Cubic							70	.5	
Total	95	108.6		191	109.9		479	109.9	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 12

Analyses of the Variance in Heart Rate Change for Experiment 3: Prestimulus Sec - First Poststimulus Sec, and All Poststimulus Sec as a Function of Presentation Type and Trial Blocks for 10 Sec Interval Condition

	Pre Sec - First Post Sec			All Post Sec		
Source	df	MS	F	df	MS	F
Between Subjects (Ss)	11			11		
Condition Order (CO)	1	3652.5	1.77	1	8153.3	1.61
Ss w/in Groups (Grps)	10	2062.0		10	5078.3	
Within Ss	276			708		
Presentation Type (PT)	3	58.8	5.35**	3	25.9	2.31
CO x PT	3	35.1	3.19*	3	8.5	.76
CO x PT x Ss w/in Grps	30	11.0		30	11.2	
Trial Blocks (TB)	2	3.7	.22	2	4.4	.18
CO x TB	2	4.6	.28	2	22.2	.93
CO x TB x Ss w/in Grps	20	16.4		20	23.9	
Seconds (Sec)	1	4.6	.95	4	130.2	21.55***
Linear				1	491.1	29.05***
Quadratic				1	22.2	3.97
Cubic				1	5.8	6.00*
CO x Sec	1	1.7	.34	4	4.6	.77
Linear				1	11.8	.70
Quadratic				1	4.6	.82
Cubic				1	.8	.82
CO x Sec x Ss w/in Grps	10	4.9		40	6.0	
Linear				10	16.9	
Quadratic				10	5.6	

Table 12 - continued

Source	Pre Sec - First Post Sec df	MS	F	All Post Sec df	MS	F
Cubic				10	1.0	
PT x TB	6	15.7	1.33	6	21.9	1.33
CO x PT x TB	6	13.2	1.12	6	12.1	.74
CO x PT x TB x Ss w/in Grps	60	11.8		60	16.4	
PT x Sec	3	1.8	1.70	12	12.4	3.58***
Linear				3	24.6	2.85
Quadratic				3	21.9	6.74**
Cubic				3	1.5	1.42
CO x PT x Sec	3	2.7	2.60	12	7.0	2.01
Linear				3	23.3	2.70
Quadratic				3	2.8	.85
Cubic				3	.7	.62
CO x PT x Sec x Ss w/in Grps	30	1.1		120	3.5	
Linear				30	8.6	
Quadratic				30	3.2	
Cubic				30	1.1	
TB x Sec	2	4.0	2.20	8	1.0	.30
Linear				2	3.0	.45
Quadratic				2	.1	.03
Cubic				2	.5	.38
CO x TB x Sec	2	.2	.09	8	1.8	.57
Linear				2	1.4	.22
Quadratic				2	5.3	1.19

Table 12 - continued

Source	Pre Sec - First Post Sec df	MS	F	All Post Sec df	MS	F
Cubic				2	.5	.40
CO x TB x Sec x Ss w/in Grps	20	1.8	.71	80	3.2	
Linear				20	6.7	
Quadratic				20	4.5	
Cubic				20	1.2	
PT x TB x Sec	6	3.8	1.45	24	4.0	1.04
Linear				6	12.3	1.24
Quadratic				6	2.3	.80
Cubic				6	.9	.45
CO x PT x TB x Sec	6	1.3	.50	24	2.9	.74
Linear				6	6.6	.67
Quadratic				6	2.2	.76
Cubic				6	1.9	.89
CO x PT x TB x Sec x Ss w/in Grps	60	2.6		240	3.9	
Linear				60	9.9	
Quadratic				60	2.9	
Cubic				60	2.1	
Total	287	92.1		719	88.9	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 13

Analyses of the Variance in Heart Rate Change for Experiment 3: Prestimulus Sec - First Poststimulus Sec, and All Poststimulus Sec as a Function of Presentation Type and Trial Blocks for 20 Sec Interval Condition

	Pre Sec - First Post Sec			All Post Sec		
Source	df	MS	F	df	MS	F
Between Subjects (Ss)	11			11		
Condition Order (CO)	1	6895.5	2.26	1	18960.4	2.53
Ss w/in Groups (Grps)	10	3057.6		10	7502.6	
Within Ss	276			708		
Presentation Type (PT)	3	28.0	2.81	3	66.9	2.27
CO x PT	3	12.7	1.28	3	22.3	.76
CO x PT x Ss w/in Grps	30	10.0		30	29.5	
Trial Blocks (TB)	2	33.9	1.81	2	87.9	3.07
CO x TB	2	46.3	2.47	2	99.2	3.47
CO x TB x Ss w/in Grps	20	18.7		20	28.6	
Seconds (Sec)	1	44.0	35.94***	4	155.7	16.77***
Linear				1	609.8	23.70***
Quadratic				1	1.3	.17
Cubic				1	7.9	3.05
CO x Sec	1	.3	.20	4	6.8	.73
Linear				1	7.1	.27
Quadratic				1	11.5	1.53
Cubic				1	7.5	2.88
CO x Sec . Ss w/in Grps	10	1.2		40	9.3	
Linear				10	25.7	
Quadratic				10	7.5	

Table 13 - continued

Source	Pre Sec - First Post Sec df	MS	F	All Post Sec df	MS	F
Cubic				10	2.6	
PT x TB	6	19.0	1.15	6	25.5	1.14
CO x PT x TB	6	6.9	.42	6	25.4	1.13
CO x PT x TB x Ss w/in Grps	60	16.4		60	22.4	
PT x Sec	3	1.9	1.24	12	6.5	1.23
Linear				3	2.7	.20
Quadratic				3	14.9	3.44*
Cubic				3	7.9	3.69*
CO x PT x Sec	3	2.1	1.40	12	11.7	2.23
Linear				3	35.6	2.66
Quadratic				3	7.0	1.62
Cubic				3	3.9	1.82
CO x PT x Sec x Ss w/in Grps	30	1.5		120	5.3	
Linear				30	13.4	
Quadratic				30	4.3	
Cubic				30	2.2	
TB x Sec	2	2.1	.69	8	1.7	.40
Linear				2	2.7	.30
Quadratic				2	3.5	.86
Cubic				2	.4	.16
CO x TB x Sec	2	1.3	.43	8	1.0	.23
Linear				2	1.7	.19
Quadratic				2	.1	.03

Table 13 - continued

Source	Pre Sec - First Post Sec df	MS	F	All Post Sec df	MS	F
Cubic				2	1.9	.75
CO x TB x Sec x Ss w/in Grps	20	3.0		80	4.1	
Linear				20	8.8	
Quadratic				20	4.1	
Cubic				20	2.5	
PT x TB x Sec	6	1.0	.37	24	4.4	.93
Linear				6	11.1	.99
Quadratic				6	1.3	.35
Cubic				6	4.3	1.51
CO x PT x TB x Sec	6	2.4	.91	24	2.3	.48
Linear				6	4.8	.43
Quadratic				6	1.9	.52
Cubic				6	2.2	.78
CO x PT x TB x Sec x Ss w/in Grps	60	2.7		240	4.7	
Linear				60	11.2	
Quadratic				60	3.7	
Cubic				60	2.8	
Total	287	139.1		719	140.8	

* $p < .05$
** $p < .01$
*** $p < .001$

APPENDIX I

Summary Table of the Analysis of Variance
in Skin Conductance Change for Experiment 3
(Table 14)

Table 14

Analysis of the Variance in Skin
Conductance Change for Experiment 3

Source	df	MS	F
Between Subjects (Ss)	11		
Condition Order (CO)	1	.01635	.02
List Order (LO)	1	.00105	.00
CO x LO	1	2.20675	2.72
Ss w/in Groups (Grps)	8	.81005	
Within Ss			
Interval Condition (ICON)	1	.11400	1.23
CO x ICON	1	.01917	.21
LO x ICON	1	.00015	.00
CO x LO x ICON	1	.14356	1.55
ICON x Ss w/in Grps	8	.09248	
Presentation Type (PT)	3	.03747	5.03**
CO x PT	3	.00322	.43
LO x PT	3	.00596	.80
CO x LO x PT	3	.02930	3.93*
PT x Ss w/in Grps	24	.00745	
Trial Blocks (TB)	2	.00540	.29
CO x TB	2	.04931	2.69
LO x TB	2	.04390	2.39
CO x LO x TB	2	.01119	.61
TB x Ss w/in Grps	16	.01836	
ICON x PT	3	.01324	.99

Table 14- continued

Source	df	MS	F
CO x ICON x PT	3	.00524	.39
LO x ICON x PT	3	.00209	.16
CO x LO x ICON x PT	3	.01051	.79
ICON x PT x Ss w/in Grps	24	.01334	
ICON x TB	2	.01639	1.23
CO x ICON x TB	2	.01883	.66
LO X ICON x TB	2	.01308	.98
CO x LO x ICON x TB	2	.02232	1.67
PT x TB	6	.00613	.62
CO x PT x TB	6	.00892	.90
LO x PT x TB	6	.00516	.51
CO x LO x PT x TB	6	.00410	.41
PT x TB x Ss w/in Grps	48	.00991	
ICON x PT x TB	6	.01051	1.32
CO x ICON x PT x TB	6	.01507	1.90
LO x ICON x PT x TB	6	.01015	1.28
CO x LO x ICON x PT x TB	6	.00620	.78
ICON x PT x TB x Ss w/in Grps	48	.00794	
Total	287	.04406	

* $p < .05$
** $p < .01$
*** $p < .001$

BIOGRAPHICAL SKETCH

Louis David Silverstein was born on November 25, 1950, in Miami Beach, Florida. He attended schools in Miami, Florida, and in June, 1968, was graduated from Miami Beach Senior High School. From July, 1968, to July, 1969, he completed his freshman year at Tel-Aviv University, Israel and travelled extensively throughout Europe and the Middle East. He enrolled at the University of Miami during September, 1969, where he completed his sophomore and junior years. In September, 1971, he enrolled at the University of Florida and received the degree of Bachelor of Arts in June, 1972. Since September, 1972, he has been enrolled in the Graduate School of the University of Florida pursuing advanced study in the field of Experimental Psychology. He was awarded the Master of Arts degree in August of 1974 and is currently completing the requirements for the degree of Doctor of Philosophy.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W. Keith Berg, Chairman
Associate Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

C. Michael Levy, Co-Chairman
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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August, 1977

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